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PERFORMANCE EVALUATION OF SMALL SCALE IRRIGATION SCHEME:THE CASE OF GOMIT SMALL SCALE IRRIGATION SCHEME ESTIE WOREDA

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A thesis submitted to the school of Research and Graduate Studies of Bahir Dar Institute of Technology, BDU in partial fulfillment of the requirements for the degree

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DECLARATION

I, Genzeb Nigussie Tizazu, declare that this Msc thesis is my own original work and that it has not been presented and will not be presented by me to any other university for similar or any other degree award, and all sources of material used for this thesis have been duly acknowledged.

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DEDICATION

I dedicate this thesis manuscript to my Sister Dasash Fikadie, my wife Tirusew Aragew and My son, Henoke Genzeb, for their affection, love and their moral support during my studies.

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ABSTRACT

Food security can be achieved through irrigation development; the efficiency of irrigation scheme is highly depending on physical, technological and environmental factors. This study was initiated to evaluate the performance of Gomit small-scale irrigation scheme using internal performance indices such as conveyance efficiency, application efficiency, storage efficiency deep percolation fraction, water delivery performance and maintenance indicators, so as to recommend appropriate measures to improve the scheme management and performance. Primary data were collected using: field observation, interviewing beneficiary farmers, discharge measurements in the canals, determination of moisture contents of the soil before and after irrigation, determination of soil physical properties and measurement of depth of water applied to the fields. In addition to primary data, secondary data were collected from the secondary sources. The results show that, the main canal conveyance efficiency was 81.6%, the average conveyance efficiency of the secondary canal was 60.51%.The conveyance efficiency of the canals was found to be very low when compared to accepted standards. The application efficiency result on three farmers' farm located on head, middle and tail of the command were 45.09%, 41.13% and 39.03%, respectively. These values were also found to be below the recommended value (60%). The water delivery performance was only 22 percent showing a very substantial reduction from the design of the canal capacity. Maintenance indicators; effectiveness of infrastructure and sustainability of irrigated area were found to be 23.25% and 41.4%, respectively. These values indicate that, actual command area was reduced from initially designed, and a number of structures initially installed were becoming nonfunctional.Assessment of farmers' perception about the performance of the irrigation scheme was conducted using structured questionnaires and group discussions. All respondents confirmed that the establishment of the scheme is very important for them to secure food self-sufficiency. The survey established that (75%) the major causes for the under-performance of the scheme are sedimentation from the headwork and/or canals.Generally, the performance of the irrigation system was poor. Therefore, the conveyance systems should be improved through regular canal cleaning and maintenance of infrastructuresand constructing flow control gates (metal sheets) are basic remedial measures.

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LIST OF ABBREVATION AND ACRONYMS

ADSWE	Amhara Design and Supervision Works Enterprise
Co-SAERAR	Commission for Sustainable Agricultural and Environmental Rehabilitation of Amhara Region
DA	Development agents
DPF	Deep Percolation Fraction
Ea	Field application ratio
Ec	Conveyance ratio
EI	Effectiveness of infrastructures
Es	Storage efficiency
FAO	Food and Agricultural Organization of the United Nations
FC	Field Capacity
GIS	Geographic information System
GPS	Geographical positioning system
Ha	Hectares
L/s	Litter per Second
MC	Main Canal
PWP	Permanent Wilting Point
ROR	Runoff Ratio
SC	Secondary canal
SIA	Sustainability of Irrigable Area
SSI	Small Scale Irrigation
TC	Tertiary Canal
WUA	Water User Association

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1. INTRODUCTION

1.1. Background

Irrigation development is an important tool to encourage the economic growth and rural development, and it is considered as a foundation of food security and poverty reduction in Ethiopia. Irrigation is one means by which agricultural production can be increased to meet the growing food demands in the country (Awulachew *et al.*, 2007). Expanding and new irrigation development is one of the best alternatives to consider for reliable and sustainable food security on various scales, through river diversion, constructing micro earthen dams and water harvesting structures. However, growing population with higher farming intensities, increasing urbanization, computation of different sectors for water allocation and environmental concerns have all combined to put pressure on water resources (Robel, 2005).Our country, Ethiopia has 12 river basins with an annual runoff volume of 124 billion meter cube (BMC) of water and an estimated ranges of 2.6 BMC to 30 BMC ground water potential. The irrigation potential is also estimated about 5.3 M ha from 15 M ha of total cultivated area (EPCC, 2015).

The irrigation area of the country is 640,000 ha. Of these 120,000 ha using rain water harvesting, 383,000 ha from small scale irrigation and 129,000 ha from medium and large scale irrigation systems (Awulachew *et al*., 2010a; EPCC, 2015).

Amhara region is one of the regions of Ethiopia which has abundant water resources. The annual runoff in the region is estimated to be 60 billion m^3 with water resources per capita of 3,570 m^3 (Melkamu, 1996). This region is one of the regions in the country with vast potential for irrigation development. Estimated potential land for large and medium scale irrigation of the region is about 650,000 - 700,000 ha and for small scale irrigation is about 200,000 - 250,000 ha, indicates the magnitude of water resources available for development (BCEOM, 1999).The study site is located within Beshilo River sub basin, which is a tributary to Abay (Blue Nile) River basin and endowed with different water sources. Hence, the government has undertaken development of several new irrigation projects; however the performance of existing irrigation schemes is given less attention and its performance is far below expectation. In the country small scale and community managed irrigation is by far dominating; these schemes play a vital role in improving the livelihoods of the smallholder farmers(Seleshi, 2010). However, existing small-scale community managed irrigation schemes face various problems related to operation and maintenance, water management and sustainability, these problems have greatly reduced their benefits and challenged their overall sustainability, so a need arises to identify which arrangement for water management in community managed irrigation schemes functions better (Bos *et al*. 1993).

The East EstieWoreda, found in south Gonder zone, is one of the areas where moisture stress is highly observed (Co-SAERAR, 2001). To alleviate the problem of food shortage the former Department of Rural Infrastructure Development in the Ministry of Agriculture implemented **Gomit** small scale irrigation project. The scheme was originally designed to irrigate 90 ha of land but currently irrigating less than 37.29 ha of land.

According to Seleshi, (2010) command area below 200ha is classified as small scale irrigation schemes (SSI); and command area ranges from 200ha to 3000ha are classified as medium scale irrigation schemes (MSI); and also large scale irrigation schemes (LSI) are above 3000ha. Based on the mentioned classification the study scheme was classified as small scale irrigation scheme.

This study was made to assess the performance of the scheme using selected irrigation scheme performance indicators. The scheme was selected based on the site accessibilityand availability of data.

1.2. Statements of the Problem

Irrigation is major importance in many countries of the World. It is important in terms of agricultural production and food security, enhancing the income of rural people and public investment for rural development. However, there is wide spread dissatisfaction with the performance of irrigation projects in developing countries (Behailu et al. 2004). In Ethiopia, scheme performance is estimates on average 36% below design capacity, implying a loss of about 230,000 ha of irrigated land, leading to only 410,000 ha irrigated.

Small scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew *et al*., 2010).

The interventions so far made in Amhara region focuses on the development of new irrigation schemes and upgrading the physical infrastructures of existing traditional irrigation schemes Tilahun (2015). Wonidmkun and Tefera (2006) reported that 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 to input supply and marketing.

Poor management of available water for irrigation, both at system and farm level has led to a range of problems and further aggravated water availability and has reduced the benefits of irrigation investments (FAO, 1996).In Gomit small scale irrigation scheme there is no any investigation or research done regarding all irrigation management activities including challenges and improvement opportunities.Yet, there is no that much well-managed irrigation water practice in the scheme as well as the communities using the irrigation scheme are not living well in their life.Theschemes are poorly equipped with water control and measurement structures. During irrigation period,due to absence of gates farmers use local materials to prevent water leakage through the offtake, most lined canals found in the scheme are silted, plant growth and sedimentation, water division structures are not operational in its full capacity.Water theft, conflict on water distribution is a common issue in the schemes. This shows that there are many problems or gaps concerning overall irrigation management activities in the scheme.Therefore, this study is found to be very importantto evaluate the performance of Gomit small scale irrigation scheme using the irrigation performance indicators.

1.3. Objective of the Study

1.3.1. General Objective:

General objective of the study was to assess and evaluate the performance of Gomit small scale irrigation scheme.

1.3.2. Specific Objectives:

The research addresses the following specific objectives.

- To assess irrigation efficiency (conveyance and application) of irrigation schemes.
- To assess the status of water delivery in irrigation schemes.
- To assess the operation and maintenance of Gomit irrigation schemes.
- To assess water management practices and institutional set up of the scheme from farmerperspective.

1.4. Significance of the Study

The study will provide information for the present performance level of the irrigation scheme. The study shall have significant contribution to understand the draw backs and best achievements across system levels. It helps to identify the strengths and weaknesses, consequently alternatives that may be both effective and feasible in improving spatial variability of performance to achieve maximum efficiency. It is also important to measure and evaluate their success or failure actually and identifies specific areas needed to be improved, and it is great interest to know how the existing water delivery structures in the scheme is actually performing at this occurrence and to determine whether the farmers are satisfied or not with the irrigation service furthermore,

The study will also provide a good input at times of planning for future irrigation projects aimed at foreseeing their future performance. Information collected from the study will help government policy makers, development agents, and NGOs to formulate appropriate policies, design effective evaluation and development programs. The irrigation practice and water management in the scheme will improve. The water losses will be minimized and water allocation to the users will be rationalized.

2. LITERATURE REVIEW

2.1 . Overview of Irrigation Development in Africa

There is growing concern about food security in Africa and especially in sub-Saharan Africa. While the aggregate global food supply/demand picture is relatively good, there will be worsening in food security in sub-Saharan Africa and cereal imports are projected to triple between 1990 and 2020; imports for which the region will not be able to pay (FAO, 1997).

When viewed at the world scale, irrigation plays a significant role in crop production. The 260 million hectares (17% of agricultural land) of irrigated lands developed to date in the world have played a key role in enabling the farming community to produce an abundance of the food at low and relatively stable prices. According to some estimates, 40 percent of the world's food supply comes from the irrigated areas (FAO, 1995). However, the African continent has not been fortunate to optimize its irrigation potential development.

FAO, (1995) reported that the total water resources potential of Africa is 20,211 Bm^3/year, out of which it uses 3,991 Bm^3/year (19.75%). Agriculture accounts for 85 % of the water used. The total irrigated land of the continent is estimated to be about 124 million ha. This figure includes all land where water is supplied for the purpose of crop production. It represents an average of 7.5 % of the arable land. One reason why Africa has not achieved a Green Revolution similar to Asia is that the research system in Africa is not strong though the challenges are great. Control of water and soil moisture in the field is a precondition for successful application of many of the results of agronomic research (FAO, 1995).

Irrigation technology focusing on irrigation techniques and efficiency has been improving since the beginning of the last century. But Jensen (1983) proposed that innovative new concepts would be needed to modernize the older irrigation systems such that the delivery systems and other factors do not limit the irrigation efficiencies. Economical irrigation systems that apply water to the fields with nearly perfect efficiency have not been developed yet.

2.2. Ethiopian Irrigation Development Profile

Traditional irrigation is very old in Ethiopia. The traditional small-scale schemes are, in general simple river diversions. The diversion structures are rudimentary and subjected to frequent damage by flood. Although traditional irrigation has long years of history, modern irrigation started in Ethiopia in 1960s in the Awash valley with the objective of producing industrial crops (Awulachew *et al*., 2007). For instance, sugar estate irrigation schemes of Wonji Shoa and Metahara were established in 1954 and 1966, respectively.

Before 1974, private capital investment in agriculture has been increasing due to the government's policy of encouraging the development of commercial farming in sparsely populated lowland areas of the country. Concessionaire farms included the Middle Awash agricultural estate Share Company of Melka Sedi banana farms (Fekadu *et al*., 2000).

The country is presently committing huge investments to develop irrigation infrastructure of different scales with the aim to enhance agricultural production to feed the growing population, creating employment opportunity, expand export earnings and supply raw materials to agro-industries. Public investment, private, NGOs and farmers own initiatives are involved in the development of irrigated agriculture(Seleshi and Mekonen, 2011).

Regarding the extent of the area currently covered with irrigated agriculture, there is no reliable information and monitoring system. According to Hagos *et al,(*2009), irrigation area in 2005/06 was about 625,819 ha. Estimate made by Awulachew *et al*,(2010) suggest that about 640,000 ha is under irrigation that includes 128,000 ha micro irrigation using rainwater harvesting, 383,000 ha small-scale, and 129,000 ha from medium and large-scale irrigation. This figure accounts 11.8% of the irrigable land, which is still low as compared to the potential, and development of other countries.

While the development trend in irrigation is promising, little attention is given to the management of existing schemes. The performance of existing irrigation schemes are low due to poor operation and maintenance services, problems related to improper planning and design, lack of incentive for proper management of water in state-run projects (Ayana and Awulachew, 2009; Awulachew and Ayana, 2011).

2.3 .Performance of Small-Scale Irrigation

Small-scale Irrigation schemes are operated and managed by the water users themselves with little involvement of government agencies in some cases (Mamuye and Mekonen 2015).Ministry of Water Irrigation and Electricity (MoWIE, 2004/5) emphasizes that in Ethiopia, these schemes have been playing a significant role in ensuring food security at household level and in improving the livelihood of the rural poor. However, absence of continuous improvement initiatives and performance monitoring mechanisms have either challenged sustainable production or have resulted in wastage and misuse of scarce water resources in these schemes.

Evaluation data can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year (FAO, 1989). According to Style and Mariño (2002), performance of an irrigation system is represented by its measured levels of achievement in terms of one or several parameters that are chosen as indicators of the system's goals. The cause of the poor irrigation performance has been blamed on technical, financial, managerial, social, and/or institutional causes. As Prasad and Jayakumar (2003) cited, Merry *et al*. (1994) stated performance assessment practices are very much essential because of their central role in effective management.

Performance assessment in irrigation and drainage can be defined as the systematic observation, documentation and interpretation of activities related to irrigated agriculture with the objective of continuous improvement(Gomo, T. &Dhavu, and K.2014). Performance assessment is an activity that supports the planning and implementation process. The ultimate purpose of performance assessment is to achieve an efficient and effective use of resources by providing relevant feedback to the project management at all levels (Molden *et al*., 2004).

According to Mekonen and Seleshi (2011) irrigation performance assessment was studied using three levels, which are national level, regional level and scheme level. Under performance problems of irrigation systems, particularly in developing countries has adversely affected the level of production of those systems. The fact that those irrigation systems are not managed in response to their performance has been identified as the main reason behind their malfunctioning (Hamid, & Mohamed, 2011). As stated by Seleshi and Mekonen (2011) whether traditional or modern, public agency or community managed many of the existing irrigation systems in Ethiopia are deteriorating in their physical structures, operation and management.

According to Tilahun (2015) only 74% of the command area of the studied schemes was cultivated with irrigated crops and the irrigation schemes serve only about 50% of the targeted beneficiaries. Operational performance assessment relates to the day-to-day, season-to-season monitoring and evaluation of system or scheme performance. Accountability performance assessment is carried out to assess the performance of those responsible for managing a system or scheme. Intervention assessment is carried out to study the performance of the scheme or system and, generally, to look for ways to enhance that performance. Performance assessment associated with sustainability looks at the longer term resource use and scheme or system impacts.

Based on Seleshi and Mekonen (2011) research result from the 312 sampled irrigation schemes only 86.5% was operational. As stated by Seleshi (2010) scheme performance in Ethiopia is an average 30 percent below design, implying a loss of about 230,000ha of irrigated land which is 640,000ha, leading to only 410,000ha performing to the expectations.

The performance of the schemes varied with the quality of the scheme design, excessive siltation, poor agronomic and water management practices, the weak level of local institutional support and organizational capacity of the respective communities (Tilahun, 2015). Generally the majority operational irrigation schemes in Ethiopia are characterized by a poor level of technical, hydraulic, operational and service delivery performance(Zeleke et al., 2015).

2.4 . Irrigation Performance Indicators

Performance indicators measure the value of a particular item such as yield or canal discharge and have to include a measure of quality as well as of quantity, and be accompanied by appropriate standards or permissible tolerances (Murray-Rust and

Snellen, 1993). In connection with main system performance, the authors concluded that the services provided by the system and the appropriate performance standards are greatly influenced by the design of that system. Improvement of irrigation method requires the considerations of the factors influencing the hydraulic process of water application to the entire field (Hlavek, 1992). The consideration of the different factors renders irrigation management a complex decision-making and field practice process (Periera and Luis, 1999).

Performance evaluation exercises are meaningful if related with certain management objectives that are defined given situation. Some key indices or terms are developed that are used to describe 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 and Skogeroboe, 1987).

Mamuye and Mekonen (2015) make an assessment of hydraulic performance evaluation of Community Managed Irrigation Scheme. They found that water delivery performance and maintenance activities of the system were found to be poor. After reviewing significant work, authors suggested that capacity building of farmers, adequate operation and maintenances of the system, improving diversion capacity of the scheme is required to improve the existing low system performance.

2.5 . Internal Performance Indicators

These indicators examine the technical or field performance of a project by measuring 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 entire region of interest (i.e. depth of root zone) uniformly and without losses. Analysis of the field data allows quantitative definition of the irrigation system performance. The performance of irrigation practice is determined by the efficiency with which the water is conveyed 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 (Seleshi and Mekonen, 2011)

Renault *et al.(*2007) indicated that internal indicators are related to operational procedures, the management and institutional setup, hardware of the system, water delivery service, etc. These indicators are necessary in order to have a comprehensive understanding of the processes that influence water delivery service and the overall performance of a system. Thus, they provide insight into what could or should be done in order to improve water delivery service and overall performance. The efficiencies of the schemes will be computed throughout seasons by conducting field measurements and laboratory activities. The analysis will be made using field data after conducting laboratory works.

For this study on-farm irrigation system evaluation (internal process indicators) include application efficiency, storage efficiency, conveyance efficiency and maintenance indicator such as water delivery performance, sustainability of irrigated area, and effectiveness of infrastructure are used to evaluate the hydraulic performance of the scheme.

2.6 . Conveyance and Application Efficiency

2.6.1 .Conveyance Efficiency

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(Bos, 1997). Significant volume of water is lost by the networks of the conveyance canals due to seepage and evaporation depending on the nature of the soil and agro-climatic zone in which the canals are located (Molden and Gate, 1990).

The concept can also be viewed as the evaluation of the water balance of the main, lateral and sub-lateral canals and related structures of the irrigation system (Murray-Rust and Snellen, 1993). It is one of several closely related and commonly used output measures of performance that focus on the physical efficiency of water conveyance by the irrigation system (Bos, 1997). The recommended values of conveyance efficiency by FAO, 1989 are given in Table 2.1

Table 2.1.FAO Recommended Conveyance Efficiency

	Earthen canals			Lined canals
Soil type	Sand	Loam	Clay	
Canal length				
Long >2000m)	60%	70%	80%	95%
Medium (200- 2000m)	70%	75%	85%	95%
Short(<200m)	80%	85%	90%	95%
Note: Values applicable when level of maintenance is considered as very good				

2.6.1.1. Losses of Water in Canals

Losses of irrigation water in the conveyance system can be a major component of the overall water losses particularly for farms located at significant distances from water sources where the main canals are long and unlined. The amount lost depends on quality of operation, and maintenance, and the nature of the soil that affects the seepage rate. The authors were point out standards and different results of irrigation system conveyance. The more researchers were studied about conveyance efficiency and conveyance loss of canals such as Arshad, Daniel (2007), Guy (2000), Gomo, and Seleshi and Mekonen (2011).

The next conveyance efficiency of canal results was found by the listed authors. Arshad *et al*. (2009) was found for lined 56.5% and for unlined 34% which was presented as 43.5% and 66% of water loss respectively. Daniel (2007) also found that conveyance efficiency of 90% for main and 83% for secondary canal. Similarly, Guy (2000), Gomo *et al.* (2014) and Seleshi and Mekonen(2011) found conveyance efficiency of 75% for lined secondary canal, 86.4% for lined main canal and 88.7% for a system consisting lined and pipe line respectively.

The conveyance loss previous researchers were also found the next results: Arshad *et al*. (2009) has found conveyance loss of 0.695 $ls^{-1}100m^{-1}$ and 1.16 $ls^{-1}100m^{-1}$ for lined and unlined respectively. Kilic (2011) also found for secondary canal value of 46.6 ls^{-1} $100m^{-1}$, and for main canal 73.4 ls^{-1} $100m^{-1}$.

2.6.2 .Application Efficiency

Water application efficiency 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 the water and to store it in the crop root zone to meet the crop water requirement (Odhiambo and Kranz, 2011). When water is diverted into any water application system such as furrows, part of the water infiltrates into the soil for consumptive use by the crop, while the rest is lost as deep percolation and runoff. The efficiency terms determine these components and compare them with the volume of water actually applied to the field is regarded as application efficiency. The term is an indication of the effectiveness of the system in reducing losses during an irrigation event (Walter, and Berisavijevic, 1991).

The application efficiency is a term initially formulated by Israelson (1950), and measures the ratio between the volumes (depth) of water stored in the root zone for use by plant to the volume (depth) of water applied to the field. Field irrigation efficiencies are influenced by factors such as soil type, field application methods, depth of application and climate. Very high values are achieved in arid climates and where water shortages prevail. However in the area where the water applied exceeds water required, indicating an over irrigation, emphases should be given to reduce the amount of irrigation water (Walters and Berisavijevic, 1991).The irrigation efficiencies vary in accordance with the type of irrigation method. Walters and Berisavijevic (1991) found that sprinkler irrigation had the highest Ea (70%) while basin irrigation for rice had the lowest (30%). Wild flooding also had low value (45%). For non-rice crops, such as dry food crops, the authors reported that the figures were not significantly different from each other (basins 54, furrows 55 and borders 58%).

FAO (1989) reported that the attainable application efficiency according to the US (SCS) ranges from 55%-70% while in ICID/ILRI this value is about 57%. Lesley (2002) suggested that it could be in the range of 50-80%. In general, according to Michael (1997) water application efficiency decrease as the amount of water applied during each irrigations increase. FAO (1989) suggested 60% attainable water application efficiencies for surface irrigation system.

2.6.3 .Storage Efficiency

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. According to Mishra and Ahmed (1990), the water requirement efficiency, is also commonly referred to as the storage efficiency. 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 become important when water supplies are limited (FAO, 1989).

Water stored in the root zone is not 100% effective (FAO, 1992). Depending on weather, type of soil and time span considered, effectiveness of stored soil water might be as high as 90% or as low as 40%.Water storage efficiency has significant impact on the crop yields and thus on the economic return on water use. The Natural Resource Conservation Service of UK recommends water storage efficiency for homogeneous soil condition to be 87.5% (Raghuwanshi and Wallender, 1998).The adequacy of an irrigation turn expressed in terms of storage efficiency, which is defined by Jurriens *et al*. (2001) as the ratio between the stored depth and the required depth. The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation. The water requirement efficiency, Es which is also commonly referred to as the storage efficiency is defined as (Mishra and Ahmed, 1990; FAO, 1989):

$$E\,s = \frac{Dsr}{Wn} * 100 \qquad (2.1)$$

Where, Es = storage efficiency [%]

Dsr= stored water depth [mm]

Wn = required water depth [mm]

2.6.4 .Runoff Ratio

Runoff Ratio (ROR) has been formulated to describe the proportion of water, lost as runoff from the field. It is defined as the ratio between the depths of water lost as runoff to the depth of water applied to the field.

$$ROR = \frac{\text{volume of runoff}}{\text{volume of water applied to the field}} \quad \ldots (2.3)$$

Losses from the irrigation system via runoff from the end of the field are indicated in the tail water ratio. Runoff losses pose additional threats to irrigation systems. Erosion of the top soil on a field is generally the major problem associated with runoff (Jurriens *et al*., 2001).

2.6.5 . Deep percolation ratio

A component of the irrigation applied to a field percolates into the soil below the root zone. Part of the water is intentionally added to the irrigation water to maintain the salt balance of the soil through leaching additional salt brought by the irrigation water itself or through capillary process from saline groundwater (Smedema and Rycroft, 1983).

Higher DPR values are indications of over irrigation. The volume of percolated water in excess of the leaching requirement is considered as lost water and is used to define the efficiency of irrigation. DPR expresses the ratio between the percolated water beyond the root zone to the volume of water applied to the field (Feyen and Dawit, 1999). The loss of water through drainage beyond the root zone is reflected in the deep percolation fraction. High deep percolation losses aggravate water logging and salinity problems, and leach valuable crop nutrients from the root zone (Walker, 1989).

2.6.6 . Overall Scheme Efficiency

According to Michael (1997), irrigation water use efficiency is the ratio between the volume used by plants through evapotranspiration process and the volume that reaches the irrigation plots and indicates how efficiently the available water supply is being used, based on different methods of evaluation. The design of the irrigation scheme, the degree of land preparation, and the skill and care of the irrigators are the principal factors influencing irrigation efficiency. Efficiency in the use of water for irrigation consists of various components and takes into account losses during storage, conveyance and application to irrigation plots to determine the overall irrigation efficiency. Identifying the various components and knowing what improvements can be made is essential to making the most effective use of this scarce resource.According to FAO (1989), a scheme irrigation efficiency of 50–60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20–30% is considered to be poor. It should be kept in mind that the values mentioned above are only indicative values.

In addition to design and other technical factors, the farm efficiency is much regulated by the operation of the main supply system to meet the actual field supply requirements and the skill of the system operators (FAO, 1997).

2.7 .Water Delivery Performance

Water delivery performance is defined as the ratio of the amount of actual water delivered by the system to the target amount (Sanaee-Jahromi *et al.* 2000). This concept serves as an indicator of the performance of an irrigation system to monitor productivity.

According to Bos et al. (1994), water delivery performance is the simplest and the most important hydraulic performance indicator are those that compare actual discharge to an intended or target discharge at any given location in the system. Sanaee-Jahromi *et al.* (2000) stated the relationship between the actual and intended as the major state variables defined in terms of an amount of water discharge. The value of designed (intended) discharge of water can be taken from the design document while actually delivered of water will be measured directly from the scheme with current meter.

2.8 .Operation and Maintenance of Farm Structure

Maintenance of irrigation and drainage systems intends to accomplish the following main purposes: (1) Assure safety related to failure of infrastructure, keep canals in sufficiently good (operational) condition to minimize seepage or clogging, and sustain canal water levels and designed head–discharge relationships (2) Keep water control infrastructure in working condition (Boss *et al*., 2005).The hydraulic performance of the scheme could also be evaluated through maintenance performance indicators; Maintenance indicators give practical information on the sustainability of the intended water level. Maintenance performance inspection of the scheme would provide to insight the feature of the conservation of the system. Bos*et al*. (1993) states that the maintenance innovations of in irrigation system have a duty of undertaking for the purposes of safety improvement, keeping water control, distribution and other infrastructures in good working condition to design in sustainable base. For this study, maintenance indicators are computed using the following parameters such as; effectiveness of infrastructure and sustainability of irrigable area.

2.8.1 . Effectiveness of Infrastructure

Regular maintenance of irrigation system component is needed to keep the system in operational condition. For this to occur, (control) structures and water application systems must be operational as intended. The ratio of effectiveness of infrastructure indicates the extent to which the system manager is able to control water. For the analysis to be effective, however, structures should be grouped according to their hierarchical importance (primary, secondary, tertiary and quaternary) and the analysis completed for each level (Boss*et al.*,2005).Generally, a deviation of more than 5% would signal the need for maintenance or rehabilitation of the physical structures (Boss *et al.*, 2005).

2.8.2 . Sustainability of Irrigated Area

Sustainability is the performance measure related to upgrading, maintaining, and degrading the environment in the irrigation scheme. According to Abernethy (1986) sustainability is the most difficult factor to encompass and refers to the issue of leaching, drainage and salinization which if not attended to properly, may shorten the systems life.

The intensity with which the irrigated area is cropped traditionally is a function of the number of crops per year grown in an irrigated area. For cropping patterns of various crops with widely different lengths of the growing period, and for plantations, however, this cropping intensity is not well-defined. To quantify the „tenure‟ of the irrigable area by a crop it is recommended to use the ratio of actual irrigated area to intend. Within the irrigated area, several negative impacts (waterlogging, salinity and water shortage due to competitive use) cause a reduction of the (actually) irrigated area (Boss *et al.*, 2005).

A further reduction of the cropped area is related to population growth and urbanization, road construction, etc. Parameters of physical sustainability (of the irrigated area) that can be affected by irrigation managers relate primarily to over-or under-supply of irrigation water, leading to waterlogging or salinity. Irrigated area sustainability refers to the percentage of change in irrigated area over the period of years (Gorantiwat & Smout 2005). Sustainability of irrigated area (SI) is measured as the ratio of existing area under irrigation to the planned irrigated area (Bos, 1997).

2.9 . Water Management and Institutional Set up from Farmer's Perspective

The equitable and efficient distribution of water is vital for its sustainable use as well as for solving conflicts at national and international level. Therefore adequate management practices are needed. Throughout the time several formal and informal institutional arrangements have emerged all focusing on the management of water.Institutions: refer to things that pattern behavior of individuals and collective entities at various levels of aggregation, rules, routines, norms, shared expectations and morals. More specifically, legal provisions related to water use, water rights, etc. Note that the term institution is used differently from the term "Organization". The latter denotes players and actors whose interaction and behaviors are governed by institutions.

Support services: refers to range of services to enhance irrigation facilities and its utilization that fall in pure public goods, pure private goods, pool goods and common pool goods, more specifically agricultural inputs, pure agricultural information, practices, etc. Services are set of operational standards set by the irrigation drainage organizations in consultation with irrigators, government and other affected parties to manage an irrigation and drainage system (HECTOR M 2006).Qualitative samples are usually small in size because if the data are properly analyzed, there will come a point where very little new evidence is obtained from each additional fieldwork unit, (Ritchie *et al.* 2013). According to Ritchie *et al.* (2013) as a very general rule of thumb, qualitative samples for a single study involving individual interviews only often lay under 50. If samples become much larger than 50 they start to become difficult to manage in terms of the quality of data collection and analysis that can be achieved, it will also take much time and budget.

3 MATERIALS AND METHODS

3.1. Description of the Study Area

The construction of the new Gomit micro earthen dam Irrigation scheme was established by commission for sustainable agricultural and environmental rehabilitation in amhara region (Co - S A E R A R) and scheme wasconstructed in 1991 E.C for satisfying the demands of the farmers located within the peasant association (now Kebele) called ziguara. Before the construction of the micro earthen dam, farmers in the area had been practicing irrigation by diverting the Gomit River traditionally.

3.1.1. Gomit Small Scale Irrigation Project

The Project is found in Amhara National Regional State (ANRS), in South Gondar, East Esie woreda about 7km to the North direction of the woreda capital, Mekane Eyesus and the Woreda capital is 25 km from zone capital Debre Tabor and 114 km from the regional capital, Bahir Dar. The study area is located at11° 33' 43" N Latitude and 38° 46' 13"E longitude at about 2375 m a s l. It is found in moist Woyna Dega agro ecological zone.Gomit Small-Scale Irrigation scheme was constructed in 1991 and totals initial command area of the scheme was 90ha.

The irrigation project has one main canal, and3 secondary canals, however according sedimentation problem only 2 secondary canals functional. There are also 8 tertiary canals but there is not functional. The Dam type is earthen Dam, its crest length is 324m and it has 20m height, 4.0m top width. The main canal maximum discharge was 221.3 l/s (Cropwat 8 software)

The map of the study area is shown in Figure 3.1.

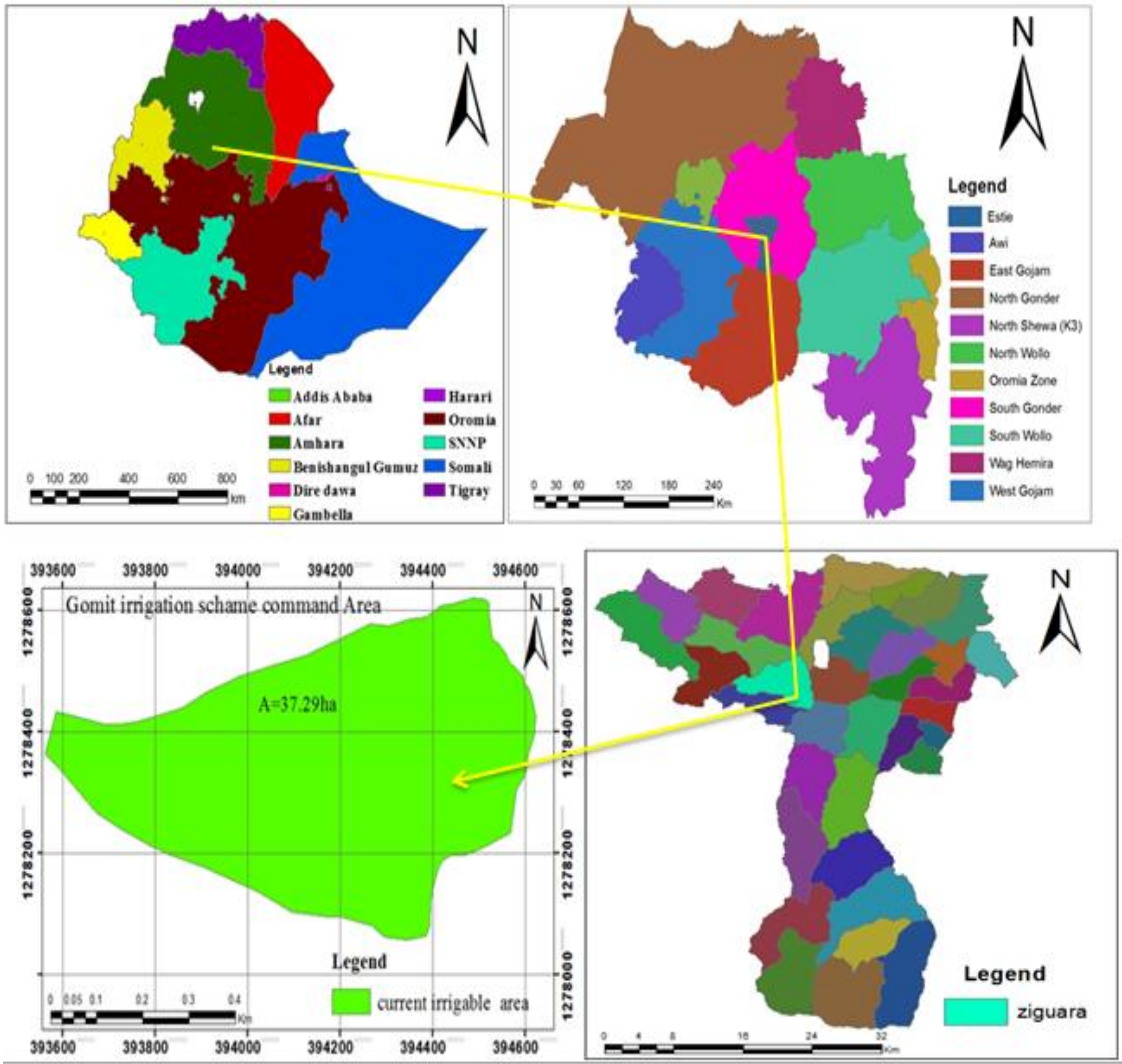


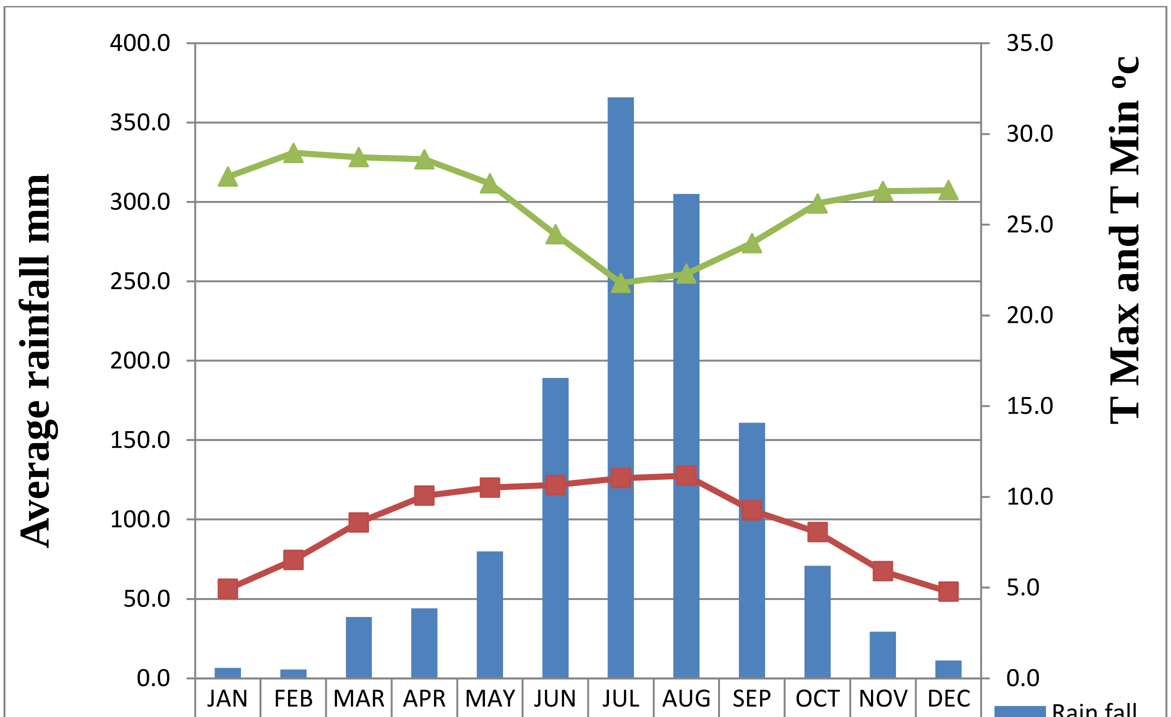
Figure 3.1Map of study Area (2017)

Geographically the woreda is found in the North Western highlands of Ethiopia and it is bounded by Blue Nile (Abay) River in the South part and the area is free from any tectonic and seismic activity or risk.

3.1.2. Climate

Climatic conditions have a basic factor on performance issues of an irrigation scheme. The monthly average values for 22 Years (1994-2016) of Climatic Debere Tabor Station were collected from National meteorological Agency,The mean minimum and maximum temperature of the study area is 8.5 and 26.2^{0}C, respectively. The monthly mean minimum temperature varied from 4.8^{0}C in December to 11.2^{0}C in August. The monthly mean maximum temperature varied from 21.8 ^{0}C in July to 29.0 ^{0}C in February.

The area receives 1307.6mm average rainfall annually. Generally, the rainfall of the irrigation area (Gomit) is characterized by its high variability in distributions. Meher or Kiremt rainfall is largely received in the four months (from June to September).The values of mean monthly rainfall, Tmax and Tmin are shown in Figure 3.2.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rain fall	6.7	5.5	38.6	44.1	80.0	189.2	366.0	305.1	161.0	70.8	29.4	11.1
Tmin	4.9	6.5	8.6	10.1	10.5	10.7	11.0	11.2	9.3	8.0	5.9	4.8
Tmax	27.6	29.0	28.7	28.6	27.3	24.5	21.8	22.3	24.0	26.2	26.9	26.9

Figure 3.2Mean Maximum and Minimum Temperature and Rainfall

3.1.3. Topography of the Study Area

The Gomit small scale irrigation scheme lies between mountains in west, south and north. The catchments area above the irrigation scheme is not vegetated and soil erosion during rainy season is a major problem causing reservoir and canal sedimentation. There was not any soil conservation structures were constructed in the fields which contribute in reducing erosion in the field during rain.

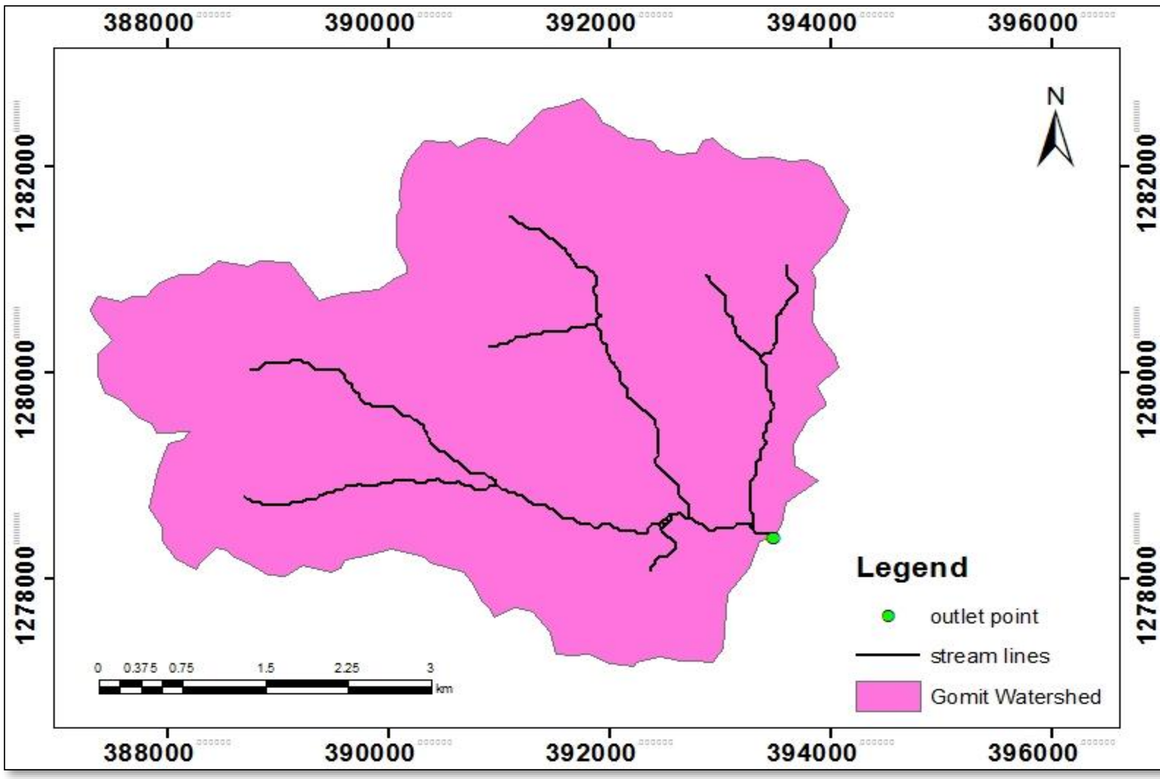


Figure 3.3. Gomit irrigation scheme Watershed area

3.1.4. Land use/ Cover

For this study a land use/cover map was collected from Ministry of Water Irrigation and Electricity (MoWIE, 2014). Gomit watershed has five types of land use/cover such as built up, cultivation land, plantation/forest land, shrub/ bush land, and water body which cover 2369.5ha. Out of the total area of the catchment, about 0.6 % is built up, 95.7 % cultivation land, 2.53% plantation/forest land, 1.1 % shrub and bush land and 0.07 % water body. The vegetation coverage of the area is very limited. The total natural forest area is 120.98 hectare. The area is facing soil erosion and environmental degradation. Map of land use/cover shown in the fig 3.4 below.

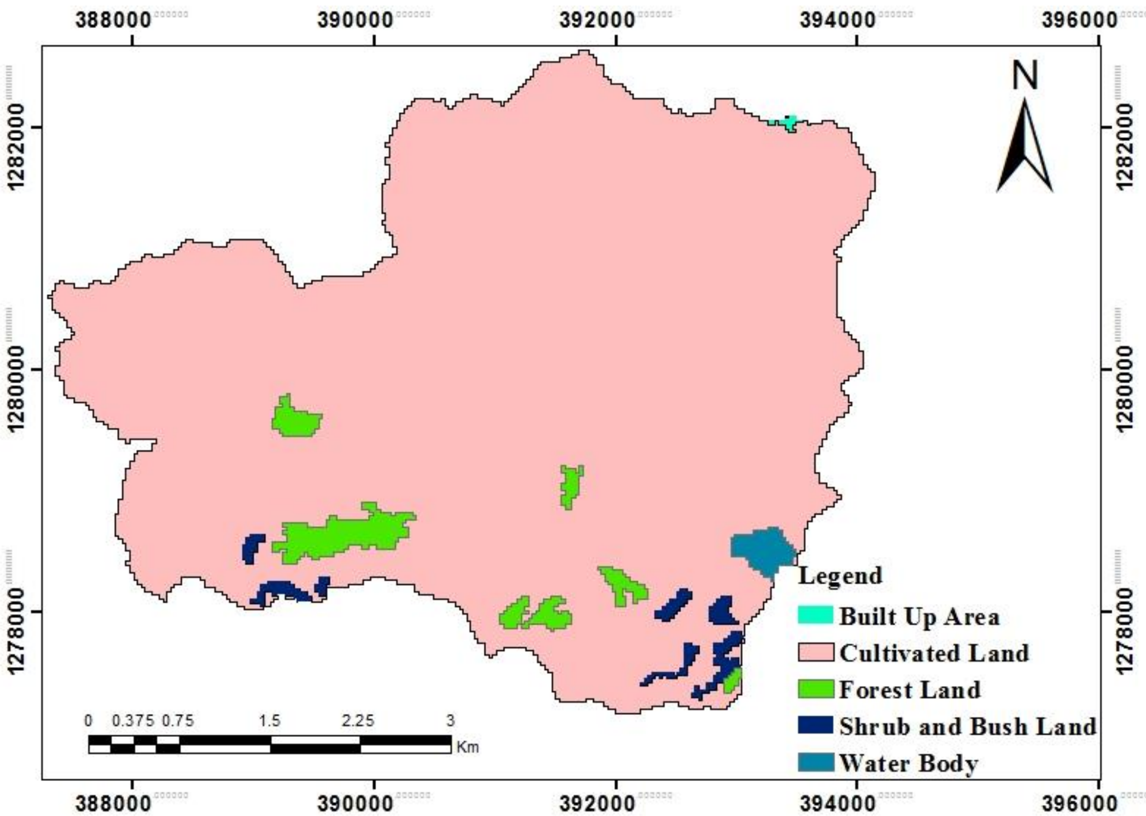


Figure 3.4: Land use/Land cover map of Gomit watershed (source: MoWIE 2014)

3.1.5. Soil

Soil can be affecting physical and chemical characteristic of plant growth, run of coefficient, and irrigation efficiency. The soil of the study area was derived from soil map shape file. Based on soil classification, two types of soil were identified. Major types of soil found in the study area are Vertisols(crack when dry and swell when wet and highly erodible) 996.6 ha and Luvisols (a subsurface layer of high-activity reddish clay accumulation and fertile soils), 1372.9 hawith a textural class of clay soil (Figure 3.5).

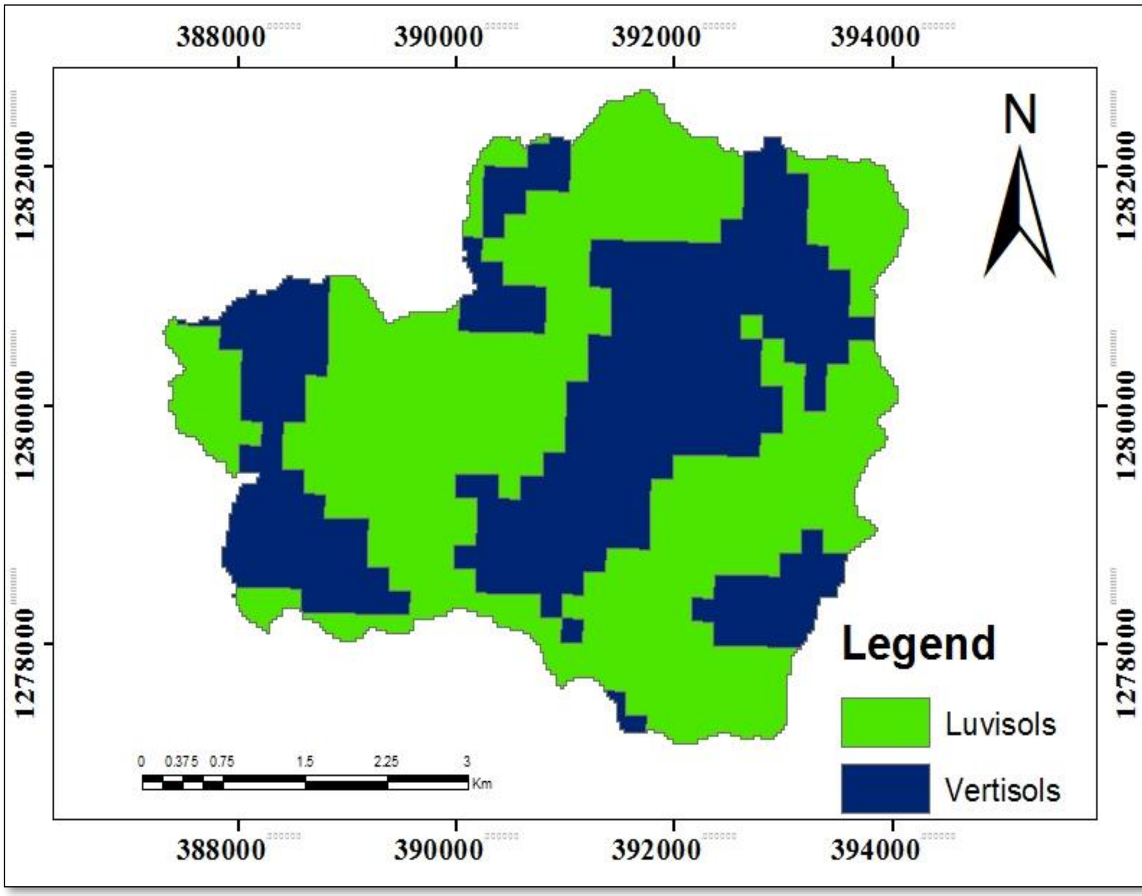


Figure 3.5soil map of the study area (source: MoWIE 2014)

3.2. Data Collection

The data collection had been carried out in collaboration with DAs in the kebele and the Woreda Agricultural Office expert. Both primary and secondary data were collected.

In general, data were collected through literature review and formal and informal communication with respective organization, interview with the aid of questionnaires and physical measurements and/or observations. Three farmers' fields were selected at the head, the middle and the tail-end water users of the command area.The criteria for selection of plot command area were location of stream that is upper, middle, and lower, their similarity with irrigation practices, crop grown and willingness of the farmers to collaborate. For Field data collection and measurement purposes, Parshal Flumes, Garmin GPS, Digital Camera, Current Meter, and Tape meter were used.

3.2.1. Secondary Data Collection

For the selected Gomit irrigation schemes, Secondary data were collected from Amhara Region Water Resource Development Bureau, Debre-Tabor Zuria Agriculture office, Amhara Design and Supervision Works Enterprise, Ministry of Water Irrigation and Electricity, Amhara Water Works Construction Enterprise, and Kebele Development. Secondary data included reports, project design documents, and other useful written materials. These data include design and layout of the scheme, design of conveyance and water control structures, irrigated area, and the role of irrigation water users association. Using questionnaire interview were made to identify key constraints of scheme performance including view of the farmers about the water supply and distribution, water control structures, rainfall amount and distribution in the past years. 32 beneficiary farmers have been selected from the head, the middle and the tail end users to provide information on farming problems and on the performance of the scheme. Much effort has been made through survey and observations of different documents at different places to check the reliability of these data.

3.2.2. Primary Data Collection

The primary data were obtained through field measurements and/or observations and laboratory analyses which include measurements of water discharge at the initial and final points of canals, soil data, irrigation delivery and structures and field irrigation method.

Transvers survey was made using hand held GPS (Global Positioning System).In this surveying, the boundary of the command area, actual canals network damage, condition of distribution structures, erosion, siltation of canal, weed growth in the canal and location of canal structures, have been located and point data have also collected.This was done by walking around the boundary of the command area and along canals and taking point data.

This point data was transferred to map source then be downloaded to global mapper and GIS software, and then digitized to locate the command area with irrigation canal network and layout within the boundary on Arc GIS (figure 3.6).

In general in the study area the following list of activities were performed.

- Formal and informal meetings with users;
- Assessing the condition of infrastructure(Beneficiary households were Interviewed);
- Discharge measurements at inflow and outflow in main, canals;
- Moisture content of the soils before and after irrigation were determined by taking soil samples at different depths (30 cm interval up to 90 cm) of the soil profiles;
- Soil samples were collected to determine soil texture, bulk density, field capacity and wilting point from the field; and
- To measure field water application, 3"Parshall flumes were installed at the entrance of the fields.

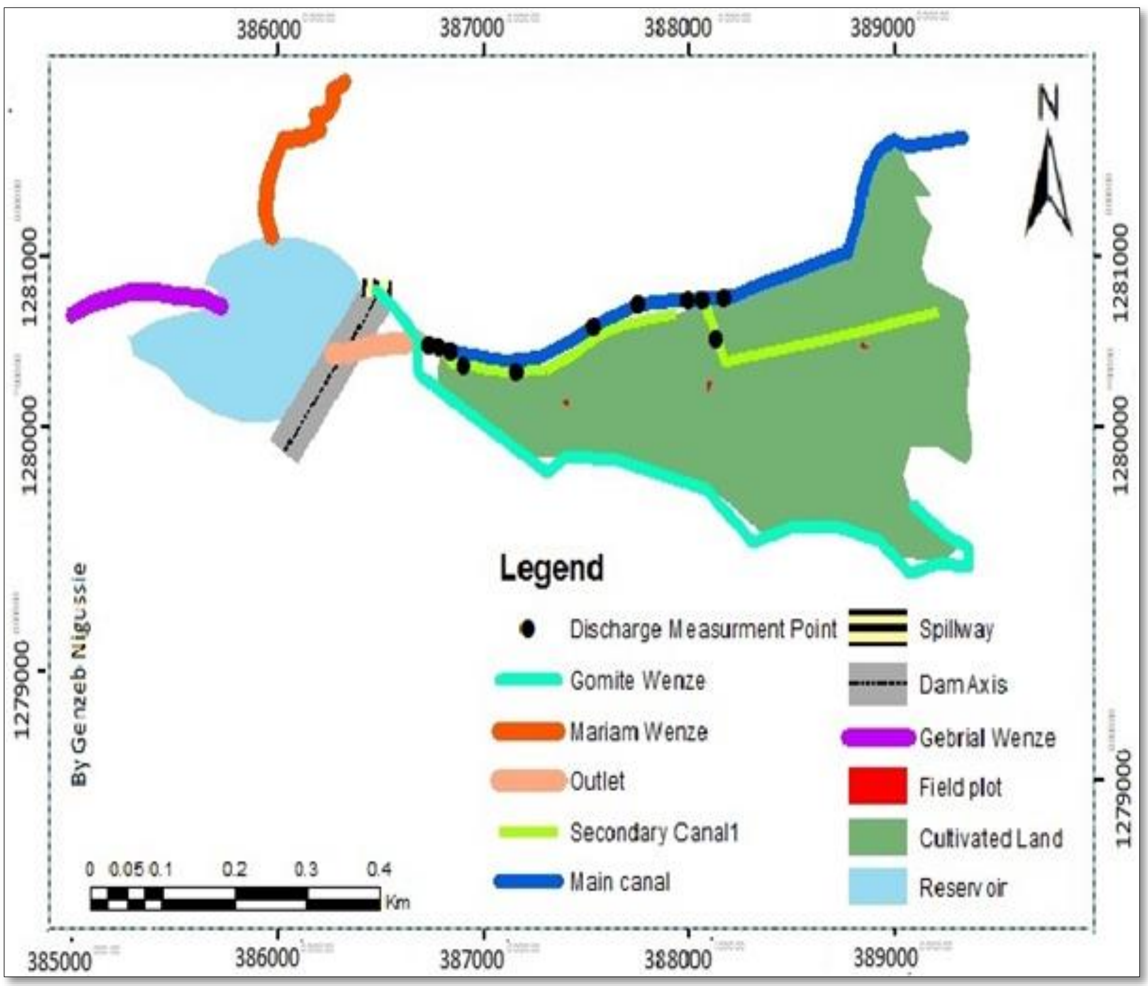


Figure 3.6Gomit small scale irrigation layout.

3.3. Sample size and Sampling Techniques

To evaluate the performance of the scheme using internal indicators, three sample experimental fields which belong to three farmers' fields were selected purposively from the head (H),from the middle (M) andfrom the tail (T) ends water users of the scheme(Shoe & Bayan,2017).

The soil type and texture class of the command area is clay (Gomit main report,). Therefore, the samples were representative of the command area. The plots of the farmers were planted most of similar crop i.e. Onion. To determine the conveyance efficiency and conveyance loss of the scheme segments of main canal and secondary canal was selected andto determine the amount of water applied by the farmers to the fields, a three inch partial flume was installed at the entrance of each field and frequent readings were taken.

In order to evaluate the farmers' perception about scheme performance and institutional aspects a sample size of 32 households was chosen out of 190 households who own irrigable land. Qualitative samples are usually small in size because if the data are properly analyzed, there will come a point where very little new evidence is obtained from each additional fieldwork unit, (Ritchie et al. 2013).According to Ritchie et al. (2013) as a very general rule of thumb, qualitative samples for a single study involving individual interviews only often lie under 50. If samples become much larger than 50 they start to become difficult to manage in terms of the quality of data collection and analysis that can be achieved, it will also take much time and budget.

From this list random sampling were used to select respondents from the total households.The data that are collected using structured questionnaire were analyzed using SPSS software package version 20 and the results were discussed using percentage of frequency and table.

3.3.1 .Soil Sampling Methods

Soil samples were collected for analyze of selected soil physical properties. These are particle size distribution, soil moisture content before and after irrigation, bulk density and soil moisture contents at field capacity and permanent wilting point.

3.3.1.1 . Measurements of moisture content of the soil

Soil sample were collected to determine soil moisture content of the irrigation field at depth interval of 30 cm to maximum of 90 cm as these depths are effective root zone of most crops. For every three plots, 54 disturbed soil samples have been taken before irrigation and2 days after irrigation from 0 -30 cm, 30 – 60 cm and 60 – 90 cm depths per test pit and were determined using gravimetric method. The soil samples were placed in containers of known weight and then weighed. The samples were dried in an oven for 24 hours at temperature of 105°C with the containers cover removed. Then the dried soil and the container were again weighed and the weights of water present were determined by subtracting the initial from the final weight.The Soil moisture contents were determined on such a way on weight and volume basis as stated(FAO, 1989).

$$\theta_W=\frac{Ww-Wd}{Wd}*100* \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.1)$$

Where:θ_W=Soil moisturecontent %

Ww = is the weight of the wet soil sample (g),

Wd = is the weight of the soil sample after oven drying (g)and then the moisture content of soil samples were converted to the volumetric water content (θv) by multiplying with bulk density (ρb) as:

$$\theta_V= \theta_W* \rho b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Where: θ_V = volumetric moisture contenton volume bases in %,

θ_W = Soil moisture content %), and

Pb= bulk density of soil (g cm^{-3}).

The purpose of calculating the amount of moisture stored in the root zone of the crop is to determine the water application efficiency of the scheme.

3.3.1.2 .Determination of Soil Texture, Bulk Density, Field Capacity and Wilting Point

Soil samples were taken to analysis the soil texture, bulk density, field capacity and wilting point. To determine soil texture of each farmer's field, 9 samples of disturbed soil were collected from three locations from each scheme at three different depths and have been determined in the laboratory using mechanical analysis and textural triangle.Bulk density of the study area was determined from undisturbed soil samples collected from three pits at interval of 30 cm starting from surface to a depth of 90 cm with core sampler volume of 98.125 cm^3 each. The samples were placed in an oven and dried at 105°C for 24 hours. The weight of the soil was divided by the sample volume to determine the bulk density(Shoe & Bayan, 2017).

$$Pb= \frac{Ms}{Vc} \ldots\ldots\ldots 3.3$$

Where, ρb = soil bulk density (g/cm3),

Ms = weight of dry soil (g), and

Vc = volume of core sampler (cm/3)

Moisture contents at field capacity and wilting point were determined using 9 undisturbed soil samples collected from 3 sampling plot at interval of 30 cm depth. The analysis was carried out through pressure plate apparatus in the laboratory. Soil moisture content was observed for the determination of field capacity and permanent wilting point at the Amhara Design and Supervision Works Enterprise (ADSWE) soil laboratory(Table 4.2).

3.3.2 .Water Flow Rate Measurement

Water flow rate measurement is a relevant data for irrigation scheme performance evaluationindicators, such as computation of canal water conveyance efficiency and water losses, evaluation of on farm water application efficiency. There are different methods to measure the flow of water in the rivers/canals. For this study Synthetic Propeller type Current Meter and three inches Parshall Flume was used for discharge measurement of main, secondary and filed off takes (Fig 3.7).Measurement was taken at full supply of the canals as given inAppendix Table 2.1 and Appendix Table 2.5. In selecting the canal segment to be measured for loss, the following conditions were taken into consideration (Australian National Committee on Irrigation and Drainage (ANCID), 2003):

a) The flow should be at normal operating condition of the canal,

b) There should be no change in water level during measurement,

c) There should be no water flow either from outside into the segment or from the segment to the outside,

d) There should be nothing to prevent the flow and,

e) Length of segment should be sufficient for measurement of conveyance losses.

Technique applied to determine losses was inflow-outflow in which water that flows into and out of canal sections and canal structures was measured. For loss measurement canal length between two points, water depth and wetted width (for top rectangular) was measured using tape mater.

Discharge of the cross section was calculated using velocity-area method at the beginning and end of segments of canals, and taken as inflow and outflow discharge of the canal. The inflow and outflow discharge of water on the selected canal reach was determined by measuring the rectangular wetted cross-sectional area and velocity of flow at the selected points of the canal.

The velocity of flow at the selected cross-section was determined using counting number of revolutions within 60 second (given value of the current meter used as stop-watch). USBR (2001) classifies different methods of determining average flow velocities. Two-point method and Six-tenths depth methods are some of the listed methods. The two-point method involves of measuring the velocity at 0.2 and at 0.8 of the depth from the water surface and using the average of the two measurements.

According USBR (2001) high accuracy is obtainable with Two-point depth method. However, the method should not be used where the depth is less than 0.6 meter. The six-tenths depth method consists of measuring the velocity at 0.6 of the depth from the water surface is generally used for shallow flows where the two-point method is not appropriate. Water depth of the study canal was below 0.6meter which is shallow, so, the number of revolutions of this study was measured by fixing the current meter propeller at 60% of the water depth from the water surface.Current meter was used for determination of water flow for main canals. Firstly, current meter was reading revolution within 60 seconds, because it made from the first to finish revolution reading within 60 seconds. Then after calculate number of propeller rotation per second (n), finally calculate velocity of flow (cm/sec) using equation 3.6.The discharge was calculated using Equation 3.4.

Q = A*V--- (3.4)

Where;

Q = discharge of water in m3/s;

A = canal cross-section in square meter; which is determined using Equation

V = mean velocity of flow of water in m/s. which is determined using Equations

A = W*D-- (3.5)

Where; A = rectangular cross-sectional area, m2; W = wetted width of section of canal, m; D = depth of flow of water in canal, m. The dimensions were measured using tape meter.

Velocity was measured without affecting canal operations, using SABA universal current meter F1 with propeller 125 mm on rod 20 mm diameter. According to the attachment from SABA HYDROMETRIE the equation being applied for determining velocity of flow is presented in Equation (3.6) and according the range of number of propeller rotation per second.

V = k*n+∆-- (3.6)

Where

Table 3.1. Coefficient of the propeller type, constant values

No	n = number of propeller rotation per second (Rev/sec)	V = the flow velocity of the water (cm/sec).	coefficient of the propeller type , constant values	
			K	∆
1	0.00 < n< 1.98	31.17*n+1.93	31.17	1.93
2	1.98 <n < 10.27	32.05*n + 0.19	32.05	0.19
3	10.27 < n < 15	33.44*n – 14.09	33.44	-14.09

3.3.3 .Determination of the Amount of Water Applied to the Fields

To determine the amount of water applied by the farmers to their fields, three inches (3″) Parshall flume were installed at the entrance of study field of interest to measure the depth of water applied to the field (Fig 3.7).

Irrigation was continuing until the farmers' thought that enough amount of water is applied to their field. After farmers completed irrigating the study field, the average depth of water passing through the flume was calculated and the discharge was reads from three inches (3″) Parshall flumes table. The total volume entered the field were calculated by multiplying discharge read from table with total time taken to irrigate. Equation3.7 (Merkley, 2006, Gertrudys, 2006 and Bos, 1989) may express the depth-flow relationship for free flow condition.

$Q = kh_1^n$-- (3.7)

Where: Q = the flow rate in m3/s,

h_1 = upstream flow depth in the converging inlet section, in m,

k = the free flow coefficient, and n = the free flow exponent,

The values of k and n are functions of the dimension of the constriction and measurement unit chosen. The value of the constant of k and n for three-inch Parshall flumes and for metric unit was 0.1771 and 1.55 respectively. The minimum and maximum discharge and head range of three inch Parshall flume was 0.77 l/s and 32 l/s and 0.03 meter and 0.33 meter respectively (Gertrudys, 2006).(appendix table 2.8)

Figure 3.7: Discharge Measurement Using Current Meter and Parshall Flumes

3.4 .Data Analysis Techniques

3.4.1 .Soil Analysis

Soil samples were collected for analysisof selected soil physical properties from selected farmer’s fields at different depths. The properties analyzed were particle size distribution (soil texture), bulk density and soil moisture contents before and after irrigation. Bulk density, field capacity and permanent welting were determined using the core sampler method. Particle size distribution was analyzed using the USDA Soil Textural Triangle method and the moisture content of the collected soil samples was determined using gravimetric method.

3.5 Evaluation of Conveyance Efficiency and on-Farm Application Efficiency

3.5.1 . Water Conveyance Efficiency (Ec)

Water distribution is the central importance of any management of irrigation systems. Conveyance system diverts water from its source, transports and distributes water to the point of use. As water is transported from the reservoir site to the irrigation field, some amount of water is lost in different ways such as seepage and linkage. Efficient irrigation system transports water with minimum losses and hence has high conveyance efficiency.

A method of measuring inflow and outflow in specific reaches using portable measuring devices (current meter) were used to estimate conveyance efficiency and water losses from this open channel. In order to determine the amount of water lost through conveyance system in the main and secondary canal, the amount of flow rate that enters to the main and secondary canal and amount of flow rate that leaves the main and secondary canal was measured.

Water transport efficiency from the source to the field is measured by conveyance efficiency.The first measurement of discharge was conducted in the upper position of the main canal. In this canal section, the cross-section of the channel was lined, uniform and rectangular in shape .Since the main canal had a rectangular lined section for part of the system, the test site was ideal for flow measurement. The width and depth of water flow in the canal was measured repeatedly and average was taken.Conveyance efficiency can be calculated then by dividing the second discharge by first discharge. By dividing the second discharge by first discharge conveyance efficiency of the canal was determined in equation 3.8.

$$Ec = \frac{wf}{\mathrm{wt}} * 100 \quad (3.8)$$

Where; Ec = water conveyance efficiency (percentage),

wf= amount of water at end point (l/s) and

wt = amount of water at source of water (l/s).

3.5.1.1.ConveyanceLoss

Water losses occur in conveyance from the point of diversion until it reaches the farmer's fields, which can be evaluated by water conveyance efficiency. It was computed by Equation 3.9:

$$TL = \left(\frac{Q1-Q2}{L}\right) \text{ -- } (3.9)$$

Where: TL is the transmission loss of the canal in $ls^{-1}100m^{-1}$; Q1 is inflow in ls^{-1}; Q2 is out flow in ls^{-1}; L is length of canal segment in 100meter.

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

3.5.2 .Water Application Efficiency (Ea)

Water Application Efficiency is a measure of efficiency of water application in the field. It is ratio of stored water to the applied water. To determine depth of water stored in the crop root zone in selected furrows soil samples were taken before and 2 days after irrigation from 0-30 cm, 30-60 and 60-90 cm soil depth for each of the head, middle and tail water users filed (Appendices 2.3). The actual amount of the water applied into each furrow was determined using three inches Parshall flume (Mishra & Ahmed, 1990) and the depth of the water retained in the root zone of the soil based on the soil moisture contents of the soils before and after irrigation, the application efficiencies (Ea)of irrigation at the selected fields were calculated using equation [3.10].

$$E_a = \frac{Ws}{Wf} \text{.. } (3.10)$$

Where Ws is Depth of water stored in the root zone of crops (mm) and,

W_f is Depth of water applied to the field (mm), were calculated using equation (3.7).

The depth (Wf) of water applied to the field was estimated by dividing the average total amount of water applied to the field by the area irrigated. The depth (d, mm) of water retained in the soil profile in the root zone was determined using the following equation given by (Mishra and Ahmed 1990):

$$d=\sum_{i=0}^{n}\left(\frac{Qf-Qi)}{100}\right)*Di*ASi \quad (3.11)$$

Where:

Q_f = moisture content of the i^{th} layer of soil after irrigation on oven dry weight basis [%]

Q_i = moisture content of the i^{th} layer of soil before irrigation on oven dry weight basis [%]

A_{Si}= Apparent specific gravity of the i^{th} layer of soil [dimensionless]

D_i = Depth of i^{th} layer [mm]

n = Number of layers in the root zone Then, the application efficiencies (Ea) of irrigation at the selected farmers' fields calculated equation (3.10).

3.5.3 . Storage Efficiency

Storage efficiency is an index used to measure irrigation adequacy. Storage efficiency of field plots was calculated based on field capacity, wilting point and root depth of particular crop at different moisture depletion level. The storage efficiency can be determined by measuring amount of water stored in the root zone after irrigation and amount of water to be needed to refill the root zone to its field capacity. The water storage efficiency was evaluated using equation (2.1).

The depth of water retained in the soil compartments of the root zone was computed by equation (3.11) and the water requirement efficiency, or the moisture deficit (Wn) in the effective root zone is found out by determining the field capacity moisture contents and bulk densities of each layers of the soil (Mishra and Ahmed, 1990).

$$Wn=\sum_{i=0}^{n}\left(\frac{FCi-PWPi)}{100}\right)*Di*ASi \quad (3.12)$$

Where: Wn = the depth of water needed in the root zone prior to irrigation (mm),

FC_i= field capacity of the i^{th} layer on oven dry weight basis

PWi= actual moisture contents of the i^{th} layer on oven dry weight basis

Asi= apparent specific gravity of the i^{th} layer

Di = depth of i^{th} layer and, n=number of layers in the root zone

3.5.4 . Deep Percolation Fraction

The runoff ratio is normally considered zero where the farmers are using furrows whose tail ends are closed, since for this study the furrows are closed end, runoff ratio is neglected. The loss of water through drainage beyond the root zone is reflected only in the deep percolation ratio that expresses the ratio between the percolated water beyond the root zone to the volume of water applied to the field. Also the evaporation from the soil is marginal and can be neglected because it is only a short period after irrigation.

Therefore, the deep percolation ratio (%)can be calculatedindirectly from the measured value of application efficiency (Ea) and run off ratio (RR) as given by FAO (1989).

$$DPR = 100 - Ea - RR \qquad (3.13)$$

Where DPR is deep percolation ratio (%), Ea is application efficiency and RR is runoff ratio (RR=0).

3.5.5 . Overall scheme efficiency

The overall scheme efficiency was calculated as the product of conveyance and application efficiency. The results obtained for different measurement points (sample plots) was assessed and analyzed to determine the condition at scheme level. It was computed using following formula (Ramulu, 1998):

$$Ep = Ec \times Ea \qquad (3.14)$$

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

3.6 . Water Delivery Performance Evaluation

The simplest, and yet probably the most important and short term, Water delivery performance indicator are those that compare actualdelivered discharge to an intended or target discharge at any given location in the system (Bos, 1997).

3.6.1 . Gross Irrigation Requirement

The gross irrigation requirement (GIR) is the amount that must be delivered discharge. GIR is greater than NIR by a factor which depends on the irrigation efficiency:

$$GIR=\frac{NIR}{E} \ldots\ldots (3.15)$$

Where

• GIR = Gross irrigation requirement,

• NIR = Net irrigation requirement, and

• E = Overall scheme efficiency.

The value of designed (intended) discharge of water was taken from the Cropwat 8 software while actually delivered discharge of water was measured directly from the scheme with current meter.

$$d=\frac{Qa}{Qi} \ldots\ldots (3.16)$$

Where: d is the delivery performance ratio (fraction); Qa is actually delivered discharge of water (m^3/s) and, Q_i is designed (intended) discharge of water to be delivered (m^3/s).

3.7 . Operation and Maintenance of Farm Structure

Proper maintenance and operation is critical to the success of irrigation and drainage systems, and to ensure that the design and operational objectives set by designers, planners, investors and farmers are achieved. The hydraulic performance of the scheme was also assessed through maintenance performance indicators. For this study two maintenance based performance measure indicators was used. Those are effectiveness of infrastructures and sustainability of irrigated area (SIA).

3.7.1 . Effectivity of Infrastructure

The assessment of the effectiveness of infrastructure was focused on the physical structures in irrigation system components including gates, the drop structures, the division boxes, and farm bridgeswere positioned on the main, secondary and tertiary canals was monitored. Effectiveness of infrastructure (EI) is the ratio of functional to total number of structures initially installed (Boss et al., 2005). The value of Effectiveness of infrastructure (EI) was computed using the following formula.

$$\text{Effectivity of infrastructure} = \frac{\text{Number of functioning structures}}{\text{Total number of structures initially installed}} \ldots\ldots\ldots\ldots 3.17$$

3.7.2 . Sustainability

According to Bos (1997) sustainability of irrigated area is the ratio of currently irrigable area to initially irrigated area. This important indicator mainly used to observe the status of the irrigation systems either contract or expanded.

compute value	status of the irrigation systems	Remark
If: <1	irrigable area contracted	water shortage, flooding problems
If : >1	irrigable area expanded	farmers to irrigate extra land

$$\text{Sustainability} = \frac{\text{current total irrigable area (Ha)}}{\text{initial Total irrigable Area (Ha)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.18$$

Where,Currently irrigable area= the area actually irrigated land (ha)

Initially irrigated area= the designed/nominal/ irrigable area (ha)

3.8 . Water Management and Institutional Set up from Farmer's Perspective

To evaluate the farmer's perception about scheme performance and institutional aspects a sample; structured questionnaire was developed and interviewed the randomly selected irrigation users. To have representative samples, the interview constituted from the head, middle and tail end of the command area. In addition to this, purposive discussions and interviews with key informants were held to get more information about the farming problems and on the performance of the scheme. Using the household questionnaires interview were conducted to identify key constraints of scheme performance including planning and management, sustainability of the scheme, conflict and conflict resolution mechanisms and support services. The data collections were carried out in collaboration with Development Agents and enumerators. During the field survey, the Keble and Woreda agricultural offices and some irrigation users were consulted about the general conditions of the scheme.

After field survey; interview, questionnaire and key informant discussions, the data were analyzed using SPSS model version 20. The process from questionnaire preparation to the final survey was fully participatory and this questionnaire is attached as Appendix 1.

Figure 3.8: Discussion with the beneficiaries of irrigation schemes

3.9 . Materials Used

The materials used in the present work were, core samplers, measuring tapes, pegs or dyes, plastic bags, current meter, Parshall flume, markers, short note, sacks, Arc GIS 9.2, Microsoft excels , Questionnaires, SPSS, and Garmin GPS etc.

GeneralMethodological frame work followed to carry out the performance evaluation was shown in figure 3.9.

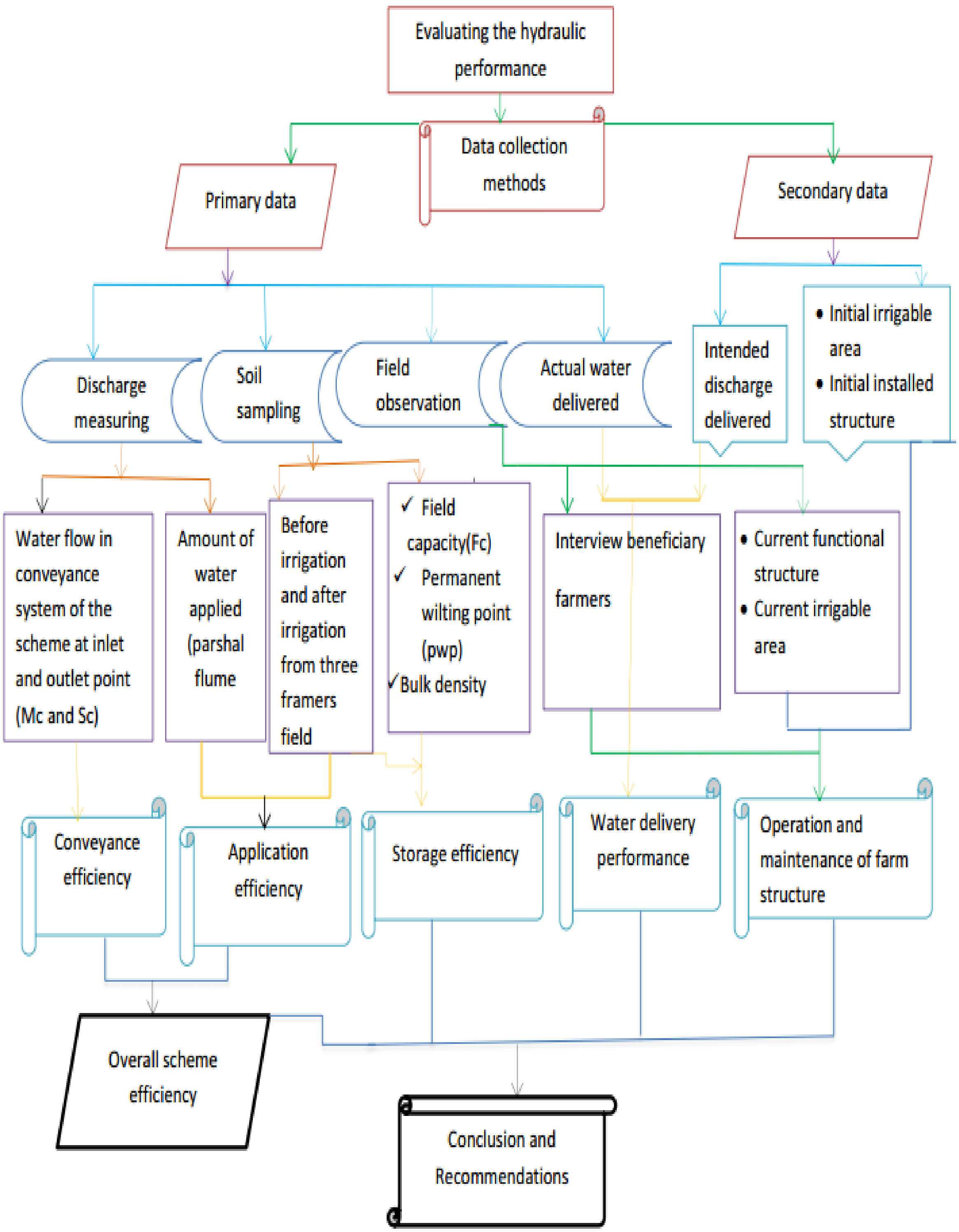


Figure 3.9: Methodological frame work

4 RESULTS AND DISCUSSION

In this study, an attempt was made to evaluate the performance of small scale irrigation schemes at south Gondar Estie Woreda, Amhara Regional State of Ethiopia using internal performance indicators. The internal performance indicators computed were conveyance efficiency, application efficiency, storage efficiency, deep percolation ratio and overall efficiency.

4.1 .Status of Irrigation Schemes and Irrigation Practices

Gomit Small-Scale Irrigation scheme currently irrigated only 37.29 ha in the irrigation season, due to reservoir and canal structure sedimentation,seepage problem.According to field measurement of the study area, main canal maximum discharge was found to be 48.5l/s. The survey result shows that majority of the division box and other canal structures were nonfunctional.

The canals were cracked, broken and silted by weeds and soils, since the canal was not fully functional. The secondary canals' were water was partly flowing through the canal, whereas the tertiary canal there was no water flow in the canal, since the tertiary canal was not functional instead farmer's uses field canals and directly from main canals and secondary canal.

The irrigation scheme has no any water flow control gates(metal sheets) at division boxes or turnouts; as an alternative farmers have uses local control materials such as: stone, soil, sacks filled with soil/sand, etc. (Appendix figure 3.4).

4.2 .Soil Data Analysis Results

Soil samples were taken at soil depth 0-30, 30-60and 60-90cm to investigate the physical properties of the soil in the Gomit's irrigation project. The soil texture, field capacity (FC), permanent wilting point (PWP), bulk density, and moisture content before and after irrigation were analyzed.

4.2.1 .Particle Size Distribution (Texture)

The term structure relates to the arrangement of primary soil particles in to aggregates. Soil structure is one of the soil physical properties, which is very sensitive to soil management practices.Based on laboratory analysis of particle size distribution using USDA SCS Soil Textural Triangle method (Appendix Figure 3.1), the soil textural class was found to be clay in the entire area. The size of the aggregates generally increased with depth due to an increase in clay content, as explained by (Brady and Weil, 2002).The study area soil type was having good storage capacity and water holding capacity, since important for plant growth.Summary of the soil particle classification at the head, middle and tail end of the irrigation scheme (Table 4.1)

Table 4.1. Particle size distribution (texture) of the Irrigation Scheme

Soil sampling location of the scheme									
Soil properties	Head			Middle			Tail		
Soil depth (cm)	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
% Sand	2 5	22	20	23	21	19	27	28	30
% Silt	32	33	32	33	30	26	34	29	25
% Clay	43	45	48	44	49	55	40	43	45
Textural class	Clay			Clay			Clay		

4.2.2 Determination of Bulk density, Field Capacity, Permanent Wilting Point.

- **Bulk density**

The bulk density of soil of the area showed a variation with depth (Table 4.2). It varied between 1.01 to 1.44 g/cm^3 and generally the top surface soil had lower bulk density than the surface. The top 0-30 cm had an average bulk density of 1.02 g/cm^3 whereas; the surface (60-90 cm) had an average bulk density of 1.44 g/cm^3. The weighted average bulk density of the soil in the experimental site was found to be 1.27 g/cm^3**.** The obtained result for surface showed a little higherthan recommended bulk density values for clay soils. This might be attributed to relatively low organic matter content and compaction effect due to overlaying material at the depth of 60–90 cm (surface).The lowest value of bulk density in the soil profile is due to higher organic matter content (Samuel, 2006). According Miller and Donahue (1995) recommended soil bulk density below 1.4 gm/cm^3 for clays and 1.6 gm/cm^3 for sands in order to get better plant growth.Thus, the study area bulk density values observed in the soils studied were within the normal range oforganic matter contentin order to get better plant growth.

- **Field capacity and permanent wilting point**

The soil moisture content at field capacity (Table 4.2) varied from 40.12% to 49.81% by volume. The soil moisture at permanent wilting point varied from a minimum value of 24.89% to the maximum value of 45.77% on volume basis.The water contents held at field capacity and permanent wilting point showed an unsystematic variation with depth of the profiles, and showed a variation with contents of clay.

Table 4.2. Bulk density, field capacity and permanent wilting point

Soil sampling location of the scheme									
Soil properties	Head			Middle			Tail		
Soil depth (cm)	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
FC(%)	40.06	36.9	34.05	39.43	34.96	30.67	40.84	35.2	31.63
FC(% v/v)	40.52	49.81	48.89	40.12	47.08	43.8	41.56	47.47	45.63
PWP(%)	24.61	29.96	31.88	27.14	27.85	28.66	28.52	28.9	28.53
PWP(%v/v)	24.89	40.4	45.77	27.61	37.5	40.92	29.32	38.97	41.15
B/D (g/cm^3)	1.01	1.35	1.44	1.02	1.35	1.43	1.03	1.35	1.44

4.3. Performance Evaluations

The performance evaluation of Gomit small scale irrigation was conducted using Performance efficiency indicators including conveyance efficiency, application efficiency, storage efficiency, deep percolation ratio, water delivery performance and maintenance indicators. Water Management, institutional and support service evaluation were also conducted to understand local knowledge on the irrigation system.

4.3.1 . Evaluation of Water Conveyance and Application Efficiency

4.3.1.1 .Evaluation of Main canal Water Conveyance Efficiency

The conveyance efficiency, Ec measures the percentage of discharge entering the system that is recorded which has been allocated to the water management units. Conveyance efficiency of the systems was computed using equation (3.2) considering the total flow delivered by conveyance system and total inflow into the system. The average calculated conveyance efficiency of the lined main canal (MC) was 81.6% (Table 4.3) which is less than FAO, 1989 recommended value of 95 % for lined main canal.High conveyance loss as given in Table 4.3 was occurred at MC middle to tail which was,this indicated that the priority of maintenance in this segment as compared to other lined segment of main canal.

The amount of water lost in averagelength of main canal (460m) was 1.6 l/s100m^{-1}or 138.2 m^3/ day/100m. This showed that 18.4% loss of water occurred in the main canal. Renault et al. (2007) about 10 to 15% of loss of water in the canal is accepted, when the result was compared to this, it not to be in the acceptable range. Factors which might account for the loss of water in the system identified were: Seepage losses, leakage losses, local water control gates, and siltation. Conveyances losses in the canal show that regular maintenance and repair work done by users were insufficient.

Table 4.3 Conveyance efficiency and conveyance loss of main canal

	Main Canal Segments			
Parameters	Main intake to MC head	MC head to middle	MC middle to tail	Average
Qin (ls^{-1})	48.5	41.0	35.2	41.5
Qout (ls^{-1})	41.0	35.2	26.2	34.1
CE (%)	84.5	85.8	74.6	81.6
loss(ls^{1}100m^{-1})	1.66	1.3	1.875	1.61
Segment length(m)	450	450	480	460

Where: MC middle to tail, MC head to middle, and MC middle to tail are Main Canal Segment,Q_{in} is flow rate of water in to segments, Q_{out} flow rate of water out of the segments and CE is conveyance Efficiency of canal in %.

4.3.1.2 . Evaluation of Conveyance Efficiency of Secondary Canals

The water conveyance efficiency and water losses along different sections of secondary canals of Gomit small scale irrigation scheme include inflow rate (Q_{in}) and out flow rate (Q_{out}) which were calculated using Equation 3.8. The calculated conveyance efficiencyvalues of each secondary canals segment as given in Table 4.4. The overall calculated conveyance efficiency of the secondary canals (SC) was 60.51 for average segment length of 305 meter.The results are below the FAO (1989) recommended value given in Table 1 which is 95% for lined canals.

The maximum loss of water was shown in SC-1 relative to other SC-2. The average conveyance loss of the SC was 3.03 $ls^{-1}100m^{-1}$or 261.8m^3 per day per 100m. The lined secondary canal water conveyance loss of this study is higher than the result of Guy (2000) which found for secondary canal value of 1.47 $ls^{-1}100m^{-1}$.

These results show that the secondary canals are less efficient from the point of view of conveyance efficiency and conveyance loss. Seepage losses, leakage losses through breached canal cross-section and leakage through field canal off-takes sedimentation and growing of weed in the canals as shown in Appendix 3.2, Figure 3.3, Figure 3.4 and Figure 3.5 were also the major factors contributing to loss of water in the canals.

The reason for this was that essential maintenance and repair work to prevent deterioration are not being conducted; operation problems, canal cleaning is not being carried out properly. On the other hand, this loss would have been avoidable with proper maintenance like avoid grasses from the canal and canal cleaning from sediment deposition.

Table 4.4: Conveyance efficiency and conveyance loss of secondary canal

Secondary Parameters	SC1	SC2	Average
Q_{in} (ls^{-1})	25.7	18.28	21.99
Q_{out} (ls^{-1})	15.60	11.03	13.31
CE (%)	60.7	60.3	60.51
loss (ls-1100m^{-1})	4.04	2.01	3.03
Segment length (m)	250	360	305

Where: Q_{in} is flow rate of water in to segments, Q_{out} flow rate of water out of the segments and CE is conveyance Efficiency of canal in %.

The summarized average conveyance efficiency and conveyance loss of the lined main and secondary canals are given in Table 4.5. The average CE and conveyance loss were 71.06% and 2.32 $ls^{-1}100m^{-1}$respectively.

Table 4.5: aver all conveyance efficiency of lined canals

Parameters	Main Canal	Secondary Canal	Average
Q_{in} (ls^{-1})	41.5	21.99	31.95
Q_{out} (ls^{-1})	34.1	13.31	24.34
CE (%)	81.6	60.51	71.06
loss ($ls^{-1}100m^{-1}$)	1.61	3.03	2.32
Segment length (m)	460	305	382.5

Generally conveyance efficiency result of the lined canal of this study was below the FAO (1989) recommended value given in Table 1 which is 95% for lined canal. The conveyance efficiency result of this study is above the result of (Arshad et al. 2009) which was found 56.5% for lined canal. (Gomo et al, 2014) found CE value of 86.4% for lined main canal which is below this study result; whereas, (Seleshi and Mekonen, 2011), found 88.7% efficiency for lined canals of a system which is above the combined conveyance efficiency (main and secondary) of this study.

The lined canal water conveyance loss of this study is higher than the average result of Arshad et al. (2009) which were 0.695 $ls^{-1}100m^{-1}$ for lined canal. The main and secondary canal conveyance loss of this study is below the average conveyance loss of (Kilic et al, 2011) which is 46.6ls^{-1}/100m for secondary canal and 73.4 $ls^{-1}100m^{-1}$ for main canal.

4.3.2 . Water Application Efficiency

The application efficiency of a given irrigation scheme tells us whether the irrigation water is stored in the intended soil profile or lost as surface runoff or/and deep percolation. The field application efficiency of the three-selected farmer's fields was estimated by the measured water application depth and soil moisture content at field capacity. In the study area observed that farmers were applying water without considering the crop water requirements.

Table 4.6. Average soil moisture content before and 2 days after irrigation

		Time of Sampling	Soil moisture contents, % Volume		
Soil depth (cm)			0-30	30-60	60-90
Sample Location	Head	Before Irrigation	26.2	27.8	29.3
		After Irrigation	32.9	34.8	36.1
	Middle	Before Irrigation	27.2	28.6	31.4
		After Irrigation	33.3	34.9	38.0
	Tail	Before Irrigation	25.9	28.5	30.0
		After Irrigation	32.6	34.5	36.1

Depth of the water retained in the root zone was computed using moisture content before and 2 days after irrigation(Appendix Table 2.6) using equation (3.11).To determine the applied Irrigation water depth installing 3 inch parshall flume at the inlet of each plots (figure 4.2).

Figure 4.1 Discharge measurement using 3 inch Parshall flume

Average applied depth of water entered into the farmers' field during irrigation events were determined by dividing volume of water applied by their respective area. Based on this the results in the head, middle and tail end are 173.01mm, 176.73mm and 182.99 mm, respectively.

The average actual water applied by the farmers ranged from173.01mm to 182.99mm that was more than the required value. This showed that the farmers were applying more water than required by the crops (Table 4.7).

Table 4.7Applied Irrigation water Measurement using 3 inch Parshall Flume

Location	Discharge (l/s)	Time lapsed (s)	Area of Field (m^2)	Total Volume (l)	Applied Depth (mm)	Depth Stored (mm)
Head	7.5	22896	992	171629	173.01	78.02
Middle	7.9	21348	960	169665	176.73	72.69
Tail	6.88	15480	582	106498.2	182.99	71.43

The above table indicates that more water was applied in the Tail-end of the scheme than in the Middle and Head reach. This may be attributed to the fact that the canal that was excavated by the farmers to convey water from the main canal to their fields do not have appropriate slope. So a considerable amount of water is lost through seepage. But highest application efficiency (Table 4.8) was recorded in the head end.

The application efficiencies (Ea) computed using equation (3.4) on the three farmers' fields is presented in (Table 4-8)

Table 4.8 Application Efficiency and Storage Efficiency

Farmer's Field	Stored depth, (mm)	Applied depth, (mm)	Ea	Stored depth, (mm)	Required depth, (mm)	Es
Head	78.02	173.01	45.09	78.02	84.45	92.4
Middle	72.69	176.73	41.13	72.69	74.87	97.1
Tail	71.43	182.99	39.03	71.43	75.64	94.4

As seen in Table 4.8, the application efficiency on the three farmers ‘fields were in the range of 39.03%-45.06%, which was considered as inefficient and indicating that the farmers were applying excess water to their fields. Mean field application efficiency of the Gomit small scale irrigation scheme was 41.75% which is below the recommended value (60%) FAO (1989), which indicates that there was not much irrigation water applied to the field stored in the soil.

Also Norman (1999):- said that a minimum value of the ratio of crop water demand to the actual amount of water supplied to the field of 0.6 (or irrigation efficiency of 60%) was included in the design of most surface irrigation systems to accommodate crop water needs and anticipated losses. Lesley (2002) suggested that it could be in the range of 50-80%. The study area application efficiency value below this limit would normally be considered unacceptable. In general, according to Michael (1997), water application efficiency decreases as the amount of water applied during each irrigation increase. Generally the application efficiency of this scheme is less than the recommended value, thus it implies the application efficiency of the scheme was poor due to the following reasons: the farmers in the area have little knowledge about irrigation water application to the field, poor scheme management, poor irrigation system design, as small scale irrigations is associated to lack of technical capacity of farmers resulted from absence of extension workers and the required trainings, absence of knowledge of irrigation time and scheduling by farmers, etc.

4.3.3 . Storage Efficiency

Storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application (Appendix Table 2.6). The water storage efficiencies (E_r) was computed by monitoring soil moisture before and after irrigations using equation (2.5) and results are shown above Table 4.7.

The storage efficiency results obtained were 92.4%, 97.1% and 94.43% for Head, Middle and Tail end user locations of the test plots respectively. According to Raghuwanshi and Wallender (1998), the recommended storage efficiency is 87.5%. Thus, the storage efficiency of the scheme indicated that the irrigation system was adequate in fulfilling the soil moisture required for good productivity of the crops.

4.3.4. Deep Percolation Ratio

Deep percolation ratio indicates the irrigation applied to a field percolates into the soil below the root zone. Higher deep percolation ratio values are indications of over irrigation.Since the irrigation scheme considered in this study is blocked end furrows, the main source of water loss was deep percolation. The deep percolation ratio calculated using equation(3.13) was 54.91%, 58.87% and 60.97 % for upstream, middle and downstream test plots, respectively (Table 4.9). From this result the high deep percolation ratio was observed at the downstream and low at the upstream location of the test plot. The result also indicates that losses are in increasing trend as the access of getting water are increasing or downstream irrigators are irrigating with maximum loss as compared to upstream and middle irrigators.

Table 4.9. Summary of field efficiencies and losses for three selected fields

Soil sample	Head	Middle	Tail
Ea%	45.09	41.13	39.03
DPR (%)	54.91	58.87	60.97

Higher deep percolation ratio was observed in lower application efficiency. During the study period it was observed that some irrigators in the downstream parts of the scheme were trying to drain out excess water from their fields by digging traditional drainage ditches. Hence, it was an implication of over irrigation which resulted in water logging problem.

4.3.5. Overall Scheme Efficiency

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 conveyance efficiency of the canals taking into account the contribution of the portion of the main canal that conveys to the sample plots and the secondary canal that goes to a particular plot, thus overall conveyance efficiency to be 71.8 percent. This study the overall scheme efficiency of the scheme was found to be 28.8% (equation3.14). According to FAO (1989), a scheme irrigation efficiency of 50–60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20–30% is considered to be poor. The result indicated that the Gomit irrigation scheme was based on the above recommended value poor.

Table 4.10. Summery average irrigation efficiencies at Gomit irrigation schemes

Internal indicators	efficiencies %	recommend value	remark
Conveyance Efficiency	71.06	Below (Gomo et al, 2014), 86.4%	poor
Application Efficiency	41.8	Below FAO (1989), 60%	poor
Deep percolation Ratio	59.28	depending on application efficiency	poor
Storage Efficiency	94.6	Above Wallender (1998), 87.5%.	good
Overall Scheme Efficiency	28.8	Below FAO (1989), 50%-60%	poor

4.4. Water Delivery Performance

Water delivery performance was the ratio of current delivered volume of water to the intended volume of water to be delivered. The scheme was designed to deliver irrigation water to individual fields based on proportional flows throughout the irrigation season. Actual water delivery service to irrigators was certainly rotational, but with unknown exact date and volume since there was no water measuring equipment found in the scheme.

4.4.1 .Crop Water Requirement

The crop water requirement and irrigation water requirement computed from the climatic data were used for the purpose of estimation of crop water productivity in terms of water consumed and also utilized as cross check for the irrigation requirement obtained from soil moisture analysis. Crop water requirement for selected crop was determined using CROPWAT 8.0 computer program.

The scheme irrigation requirement was calculated with CROPWAT 8.0 using the climate data, cropping pattern, planting dates, and area coverage of individual crop for the cropping season of 2016/2017for the purpose of determining peak irrigation requirement. The net irrigation requirements of the scheme and irrigation requirements for actual area irrigated results obtained from the CROPWAT 8.0 a represented in appendix Table 2.20. The climatic data used for the program is presented in Appendix Table 9, 10 and 11.From the computation of the CROPWAT model the peak net irrigation requirements was occurred in April, 2.9mm/day (Appendix Table 2.20).

The intended amount based on theCROPWAT model was 221 l/s. The actual delivered\ volume of water through the main canal (The mean flow of the intake) was 48.5 l/s (Appendix Table 2.4).Measurement of discharge in the upper position of the main canal was made repeatedly using current meter. Hence the delivery performance is approximately 22 percent (equation 3.15). A 78 percent reduction in the capacity of the system was too large. These indicate the actual delivered volume of water through the main canal is much less than the intended volume.

The reason for the reduction is that there is illegal obstruction of flow across the canal; this led to reduction of flow velocity, sediment of the reservoir, sediment of the outlet structure, sediment of the canal, growing of weed in the canal, seepage and destruction of the gate due to poor management of the scheme.

4.5. Operation and Maintenance of Farm structure

Maintenance system is designed to keep canals in sufficiently in good condition to minimize losses and sustain design discharge-head relationships, safety and keeping water control infrastructure in a safe working condition. To measure maintenance performance assessment as effective of infrastructures, irrigation control equipment's is important.Maintenance of irrigation schemes includes cleaning of canals when filled with grass, stone and mud, mending the canal when there is damage or broken, which enables the canal to be functioning properly and protect water lose. In addition to this the sustainability of the structure was addressed. Control structures in the scheme are head regulators, sluice gate, division boxes and culverts.In this study operation and maintenance performance of Gomit small scale irrigation scheme was evaluated by selected maintenance performance indicators'. Performance indicators are effectiveness of infrastructures and sustainability of irrigable area.

4.5.1 .Effectiveness of Infrastructures

From maintenance performance indicator, effectiveness of infrastructure is the first and it defined the ratio of currently functional structures to the total number of structures installed initially during the construction period. According to Mamuye, (2015) irrigation structures are categorized according to its working condition as 'operative, nearly operative, nearly inoperative and inoperative'. The last two cases can happen if one of the following conditions is present: scouring of canal section, broken of structures, missing of flow control and distribution network, damaging of the structure, sedimentation and weed growth.

According to the design document, the total number of structures initial installed in the irrigation scheme was 86, however currently functional structure was surveyed or gathered by walking through and inspection of the irrigation structures at headwork and along the irrigation and drainage conveyance system (main, secondary and tertiary canals) of the schemeonly 20 structures are functional,It calculated by equation 3.15 and the result is given in (Appendix.Table 2.7).

Therefore, the value of effectiveness of infrastructure is found to be 23.25 percent. This value indicates that more than 76.75 percent of initially installed of farm structures were not working efficiently and this shows high infrastructure maintenance is required.This problem was one of the factors which affect the performance of the scheme. Division boxes and drop structures that are found in the scheme are destructed and did not provide the purpose of distributing irrigation water to canals (figures 4-3).

Figure 4.2Nonfunctional division box

4.5.2 .Sustainability of Irrigation

Sustainability of irrigated area indicates weather the area under irrigation is contracting or expanding right from commencement of the scheme. It was a useful indicator for sustainability of irrigation schemes. SIA is the ratio of currently irrigated area to that of initially irrigated area and calculated according to equn.3.17.

The study of Gomit, small scale irrigation scheme indicated that, the actual irrigated area during the design period was 90 ha. Currently irrigated area was surveyed using GPS by rotating throughout the command area boundary. In addition, the data of currently irrigated area was taken from Estie Woreda Agricultural office and then compared with that gathered by GPS. The office was documented the currently irrigated area that obtained from WUAs that gathered from individual users. The two data of actually irrigated area was almost equal with that of gathered by GPS. For this research, the data taken from GPS 37.29ha was used for its accuracy.The computed values of sustainability of irrigated area at Gomit schemes were below one, according to Bos (1997): if the compute value is small or less than one it shows the irrigable area is contracted, there for the study result show that the irrigable area contracted: - which indicates the current irrigable area is below the irrigable area proposed during the construction period of the irrigation scheme.

Generally sustainability of irrigated scheme as 41.4% during this study conducted. From this, we conclude that, during the study 52.71ha (58.6%) of irrigated area was out of production by irrigation while the resulting achievement is far from satisfactory. This problem mainly observed at tail end of the command area.The main reasons farmers raisedwere water shortage; i.e.reservoir sedimentation, the hydraulic structures have been out of function, (i.e. cracking, silting), specifically the Secondary andTertiary canals were highly damaged.

The regional government and District administrative office in collaboration, they have tried to reduce the problems by excavating the sediments using machine and by constructing check dams (Gabions).

4.6 .Water Management and Institutional Set up from Farmer's Perspective

TheWater Management and institutional support services situation was assessed with the help of community meetings of all the dwellers and beneficiaries, interviews of sample beneficiary farmers.

4.6.1 .Institutional Aspect

The institutional performance indicators such as the working condition of the WUAapproach and attitude of the farmers to WUA were studied through focus group discussion, key informant interviews and beneficiary farmers were selected randomly from 190 households' in the study area. From the beneficiary farmer respondents 65.6% were illiterate, 6.2% read and write and 28.2% were primary education complete. All respondents were scheme beneficiaries

a. Planning and Management

Gomit small scale irrigation scheme WUAs were established after construction completed, during the 2nd year of the implementation period of 2005E.C. The WUA is responsible for water distribution, system maintenance, assessment and collection of irrigation water fees, input supplies, credit facilitation, planning and monitoring. But none of these responsibilities have been achieved. According the respondent of this study,93.4 percent respond there is no water user association and 6.6 percent respond there was water user association but not strong.

Table 4.11 water users association

Is there water users association in your locality?	Frequency	Percent
Yes	2	6.6
No	30	93.4
Total	32	100

All respondents confirmed that the existing WUA committee has no idea how to collect water fee from the beneficiaries.Hence, there are no operation and maintenance fees collected.

Thus Water User Association does not full financial and material for the operation and maintenance of the irrigation system.Beneficiaries and the committee have no role in scheme maintenance even if canal cleaning. As a result, canals and other structures are not maintained properly.Therefore study area needs to strengthen the capacity of WUAs through giving up to date training and, make monitoring and evaluation of their status with correction measures. Furthermore in Gomit irrigation scheme needs restructuring WUAs committees.

Table 4.12 Participation of beneficiary in the construction the structure process

Who initiate the idea of construction the structure	Frequency	Percent
Local people	20	62.5
DA	4	12.5
Project Staff (technical staffs)	0	0
Government	8	25.0
Total	32	100

As indicated in the survey result (table 4-12), 62.5 percent of the respondents said that the project was initiated by the local people while 25 percent of respondents admitted that the government and 12.5 percent DA had initiated the project. This implies that there is an agreement on who was involved in construction and development of the scheme.

Table 4.13 Participation level during Implementation of the project

Did you participate during construction of the scheme	Frequency	Percent
yes	30	93.8
no	2	6.2
Total	32	100

The study and designs for all headwork and irrigation networks were formulated and produced by Co-SAERAR. According to the respondents in this research 93.8 percent of the respondents reported the community participated during construction of the scheme through payment in the form of money (Table 4-13). Only 6.2 percent of respondents reported that they were not participated in the construction of the scheme .Moreover, most of the respondents respond that agree on the location of dam site

Table 4.14 Participation of households in the project approval

Have you been consulted for the scheme approval	Frequency	Percent
yes	21	34.4
no	11	63.6
Total	32	100.00

Beneficiary Farmers were interviewed if they were consulted during project construction, 34.4 percent respondent farmers responded that they were consulted. However 63.6 percent farmers confirmed that were not consulted(table 4.14). This leads to low group discussion within farmers in planning of the project, which decreases farmers' sense of ownership, responsibility for operation and management and will affect sustainability of the project.

b. Water Management

The water distribution is decided by the beneficiaries themselves with no predetermined schedule (without specifying the date and queuing order of each beneficiary). All respondent confirmed that water distribution to each farmer is decided by themselves based on their irrigation schedule.

The household with the rotation were use the water for that day until he/she completes irrigating the fields. According to all respondents, every member in the scheme has the right to get irrigation water and is free to grow a crop he/she wishes. The irrigation time in the scheme is 24 hrs. This showed that the WUA is not legally recognized and lack of power to discharge its responsibilities and maintenance obligation are impeding their effectiveness. This has reduced the overall performance and sustainability of Gomit irrigation scheme.

According to respondent reported, 56.2 percent farmers said that the criteria to irrigate during the irrigation time, by checking the soil moisture near the root, 31.3 percent of the respondents replied that they irrigate their crop when the soil near the crop roots is dry; and 12.5 percent of the respondents replied that they will wait until the crops leaves wilt (table 4.15).

Table 4.15Response of households on the criteria to decide when to irrigate

What criteria do you use to decide when to irrigate	Frequency	Percent
Wait until the crops leaves wilt	4	12.5
Check the soil near the roots	18	56.2
When it is dry	10	31.3
Total	32	100.0

Some of the major problems that the farmers face includes canal fill by sediment, growing of weeds and siltation of canals due to management problem. These were also in clear evidence during the survey. The canal maintenance should be the duty of the beneficiary farmer and WUA, However, the status of the primary and secondary canals and their water control structures showed that no proper maintenance (annually not clean canals by removing sediments and weeds) has been carried out for a long time and the association was not effectively shouldering the scheme management.

c. Sustainability

Participating users during planning and construction period had a positive contribution to create sense of ownership and to assure sustainability. Farmers must be increasingly responsible for managing the scheme including the operation and maintenance. In order to ensure long term sustainability for repairing and maintenance of the scheme, labour contribution was made by beneficiary farmers.However, the government has been making huge investment in irrigation scheme design and construction without participation of the community in the area. This leads to dependency on the government which decreases farmers' sense of ownership and responsibility for operation and management. Thus, study area beneficiary farmer were interview 62.5% of the respondents confirmed that they do not undertake even minor maintenance of the scheme (Table 4.16). 69 percent of respondents said that they are live, it is not my responsibility to participate in maintenance of the scheme and the other 31 percent respondent said that they do not know how to do it.

Table 4.16Ownership level of beneficiary households

Have you ever participated in maintenance of the irrigation scheme	Frequency	Percent	If you do not make the maintenance, what is the reason?	Frequency	Percent
Yes	12	37.5	a. It is not my responsibility	22	69
no	20	62.5	b. I do not know how to do it	10	31
Total	32	100.0	Total	32	100

Handing over of irrigation systems to farmers, upon completion of construction, has been a standing procedure in small-scale irrigation development. It is based on a desire to decrease the resource burdens of the government for irrigation operation and maintenance and to enhance the long-term sustainability of irrigation systems through local management and control. However, all respondents' farmers in the scheme are dissatisfied and have no ownership feeling because of many non-functional structuresand absence of proper handing over procedures. Gomit small scale irrigation scheme was constructed

1991E.c, thus most of the structures are non-functional; this was confirmed by 100 percent of the respondents (Table 4-17)

Table 4.17Response of households on the current status of the scheme

Do you see any failure on the scheme	Frequency	Percent
Yes	32	100.0
no	0	0
Total	32	100.

The beneficiary farmer 50 percent of the respondents believe that the major cause of failure of the scheme is sediment problem of the structure. 28 percent of the households also responded that there has been Structural failure and 22 percent Seepage from the head work and canals and other structures (table4-18).

Table 4.18 causes of failure of the scheme

What are the causes of failure of the scheme	Frequency	Percent
Seepage from the head work, canals and other structures	7	22
Structural failure	9	28
design problem	0	0
sediment problem	16	50
Total	32	100.

Due to the accumulated sediments and growing of weeds in the main and secondary canals, including intake and off take, the amount of irrigation water supply have been not sufficient to fulfill the requirement. Therefore it recommended that, the following improvement options should be applied to mitigate this problem; the farmers must have apply routine maintenance (sediment and weed removal from intake and off intake canals)

d. Conflict and Causes of Conflict

Conflicts /dispute on irrigation water users commonly occur in many stages; among users in the irrigation system, between users and WUAs, and between downstream and upstream users.Due to shortage and inequitable allocation of water, conflicts are arising among irrigators. According tothe respondents 84 percent confirmed that there is serious conflict on the use of irrigation schemebecause of water allocation problem (Table4-19).

Table 4.19 Response of households on conflict

Is there any conflict on the use of irrigation scheme	Frequency	Percent
Yes	27	84
No	5	16
Total	32	100.

The major causes of conflicts in Gomit SSI scheme were Water theft, Water management (unfair distribution) and Water shortage. According to the household respondents the conflict is due to the problem of conflict between irrigation users in the scheme is due to the fact that water not equally available to all users in the scheme 40.6 percent. Moreover 9.4 percent of the respondents believe that conflict is due to the problem of water theft or unauthorized canal breaching in the scheme. The upstream community often uses more amount of water than that of downstream irrigators. According to the beneficiary 50 Percent of respondents replied that cause of conflict was shortage of water.(Table 4-20).

Table 4.20Source of conflict in the irrigation scheme

What is the common source of conflict	Frequency	Percent
Water shortage	16	50
Land Shortage	0	0
Water Theft	3	9.4
Water management (unfair distribution)	13	40.6
Total	32	100

e. Support Service

i.**Input Supply**

Proper utilization of modern farm inputsSupplysuch as improved seeds, fertilizers, pesticides and fungicides are plays a significant role in increasing agricultural productivity and enhances farm households ‘food security status. Inthe study area, most of the respondent farmer beneficiaries confirmed that,the input supply, especially fertilizer and high yielding seed varieties from the government agencies is good during the rainy season but there islack of input supply during dry season when irrigation is practiced intensively. As a result, farmers in the area get inputs through farmers to farmers' seed exchange mechanisms.Generally the farmers across the study site were found to be not satisfied in using such modern farm inputs and agricultural farming practice in dry season.

ii. Extension and Training

Given the potential benefit that the scheme could provide to the beneficiary farmers and the local community, a qualified extension agent would have been authoritative.However,the study area beneficiary farmer's respondents report show thatwere not got adequate capacity building training on overall operation, utilization and management of irrigation scheme. Regular capacity building training on over all irrigation water management, irrigation agronomy, scheme operation and maintenance should be given to beneficiary farmers in order to make the scheme sustainable.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 .Conclusions

The principal objective of evaluating the performance of irrigation systems was to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency. The optimum use of irrigation water was a fundamental aspect to reach a sustainable agriculture. This study was initiated with the purpose of evaluating the performance of Gomit small-scale irrigation scheme by using performance indices.

The study shows that the idea of constructing the irrigation scheme on the site was initiation of the government, DA and the local community. However,beneficiary farmer participation in the operation and maintenance of irrigation scheme was very low in canal clearing and regular maintenance.

The overall conveyance efficiency of the canal was 71.06%, these canals were poorer due to seepage, and plants/grasses grow and canal sedimentation and damaging of the flow control structure.

Field application efficiency of the schemewith average value was 40.5%these efficiency values are below acceptable standards for similar surface irrigation systems.

The average storage efficiency of the scheme was 94.6%; this value indicated that fulfilling the soil moisture required for good productivity of the crops.

The water delivery performance was found to be 21 % indicating a substantial reduction in the capacity of the canal.

The Performance of the scheme in relation to maintenance has been generally poor. Due to the canal structures are affected by sedimentation, stone filling and weed growth, linkage and seepage problems.

In general, the performance of Gomit small scale irrigation system was poor.Reasons for poor performance of irrigation system were; malfunctioning of flow control anddistribution structures, lack of proper maintenance andoperation of water delivery system , sedimentation of canals, presence of dense vegetation in the canal, absence of the

WUAs, lack of community participation, lack of supportive training for irrigation water application and management.

5.2. Recommendations

Based on the above conclusion the following recommendations are put forward to improve the performance of the scheme.

- Water conveyance efficiency of the system is unsatisfactory, so, all canals require continuous supervision and maintenance to keep them free from weeds and reducing the deposition of silt. Continuous removal of sedimentation, preventing large logs and debris throwing into the canal, constructing water control structure across the canal and canal bank protection are some of the necessary activities. Therefore, WUAs and the beneficiaries' farmers should work together in coordination with each other.

- To improve field application efficiency and overall water productivity of the scheme,farmers should apply irrigation before or at the time when the readily available soilwater is depleted and avoid over irrigation (deep percolation losses that may leachrelevant nutrients out of the root zone), by applying irrigation to the depth smallerthan or equal to the root zone depletion.

- Regular capacity building training on over all irrigation water management, Irrigation agronomy, scheme operation and maintenance should be given to beneficiary farmers.

- Institutional support and continuous monitoring and evaluation of the scheme are necessary to take immediate correction action on the problems created on the scheme; and to provide feedback information important for the future planning of management of new schemes and maintenance of old ones..

- Rehabilitation for various irrigation scheme components was needed. Thus, the financial plan has very necessary to carry out the rehabilitation work including; replacement of void structures, weed and silt clearance in the canals, repair of canal sluice gates and head regulators and to cover other operation and maintenance expense. Therefore collection of irrigation service fees should be applied to undertake operation and maintenance activities.

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APPENDIX

Appendix-1Questionnaire`

Dear respondents,

My name is Genzeb Nigussie from Bahar Dar University, Ethiopia. I am conducted a study on the Performance Evaluation of Small Scale Irrigation Schemes .The Case of Estie Woreda**.** The main objective of this questionnaire is to recognize the problems of irrigation scheme, which is used for the stockholders to follow appropriate management plans. This is therefore; I am kindly requesting you to give a response as much as you can. All the questioner targets on the head, middle and tail reaches of the scheme and collects at household level and group discussion.

Zone__________________	Woreda______________	Keble____________________
Project Name________	Farmer's Name_________	Date_________________

A. Socio-economic Characteristics of Farmer

.1. Household head: Male: _____ Female: _____

1 Educational levels

illiterate		primary		diploma and above	
read and write		Secondary			

3 Do you know **Gomit** irrigation scheme? Yes/No

4 If yes; when was it constructed? ....

5Do you think the project was important in your area? Yes/No

6If yes, has the use of irrigation increased your annual income? Yes/No

7If yes, what is the estimated proportion of increment in the amount of income from crops compared to before the project time? …………….

8Has the number of meal time per day in your household increased due to the irrigation project? Yes/No

9 If Yes, the number of meal/day: Before ……………. and after the project ……………

10Do you feel that your wealth status improved after you started using the irrigation project? Yes/No

11Is it possible to increase the economic benefit of the irrigation scheme more than its current level? Yes/No

12If yes, what should be done to achieve it? ....

13Is there any change on the work load of women due to irrigation project? Yes/No

14Who manages and control the irrigation scheme?

a) The community as a whole		c) Kebele or PA administrators		e) Others (Specify):	
b) Representatives of the community		d) Water User Association			

15Is there any conflict on the use of irrigation scheme? Yes/No

16If yes, what do you think is/are the common source(s) of conflicts?

a) Water shortage		c) Water theft		e) Others (Specify):	
b) Land shortage		d) Water management (unfair distribution)			

17Is water equally available to all users in the scheme? Yes/No

18. Is there problem of water theft or unauthorized canal breaching? Yes/No

19Do you foresee any conflict on the water use in the future? Yes/No

20. If yes, what will be the causes? ....

21What should be done to avoid the conflict? ....

B. Project Evaluation

I. Planning

22Who initiate the idea of constructing the structures?

a) Local people		c) Project staff		e) Others	
b) DA		d) Government			

23 If it is not the local people, have you been consulted or participated for the scheme approval? Yes/No

24If not consulted, why……………

25If yes have you agreed? Yes/No

26How was the planning process?

a) Group discussion		c) Simple information by PA leader	
b) Simple information by Das		d) Simple information by project personnel	

27 Have you participated in planning of any project? Yes/No

II Design/ layout

28 Who design or put the layout of the structure?

a. DA		c. Woreda expert	
b. Project staff		d) Others	

29 Are you agreed on the project/dam site? Yes/No

30What is your opinion about the site of the dam? ……………………………….

31 Did you face any problem because of the site selection? Yes/No

32If yes, what was the problem? ………………….

III Implementation

33 Do you participate in the construction of the diversion structure and irrigation canals? Yes/No

34If yes, in what way you participate?

a. Voluntarily without payment		c. Through payment in the form of money		e. Both with and without payment	
b. By rule without payment (mass mobilization)		d. Through payment in the form of food aid (EGS)			

35 Do you use the irrigation project by now? Yes/NoIf No, why?.............................

36Do you know the cause of failure? Yes/No

37 If yes, what are they?

a. Seepage from the head work and/or the canals and its structure		c. Design problem	
b. Structural failure		d. the dam fill by sediment	

38. Do you expect these failures?Yes/No   If Yes, why? ....

39Do you see any structural failure? Yes/No

40 If yes, which structures?

a. The head work		c. The spillway		e. All	
b. The canals		d. The canal structures		d. Other structures (indicate)	

41Do you see any seepage on the headwork, canals and canal structures? Yes/No

C) Institutional supports

42Do you have access to different input supply for irrigation? Yes/No

43Did you use improved seed, fertilizer, chemicals and hand tools? Yes/No

443 If yes, explain improved technology use in the year 2008……………..

45Do you use agricultural inputs as per the recommended rate? Yes/No

46Do you have responsible institution that supply input for irrigation farming as per the schedule of your irrigation practice? Yes/No

D) Organizations

47Is there water users association in your locality? Yes/No

48If yes, are you a member of water users association? Yes/No;If yes, how was the association formed?

49If you are the member of WUAs, what benefits do you get from being a member?

a. Irrigation water on program basis		c. Adapt social accountability and responsibility	
b. Economic water use		d. All	

50As a member of WUA what is your contribution for the sustenance of the scheme?

a. Cost sharing		c. Others	
b. Labour contribution			

51Generally, how do you perceive the overall contribution of WUA to the scheme functioning and sustenance?

a. It has positive contribution		c. Not known	
b. No contribution at all			

52Do you think your WUAs strong? Yes/No

E) Water Management

53What criteria should you used to decide when to irrigated crops?

a. .Wait until see signs of wilting on the leaves		c. When it is dry, I irrigate	
b. Check the soil near the roots		d. Irrigate every day	

54Do you think your yield is reduced because you cannot apply enough water to your crop? Yes/No

55Who makes decisions on the sequence of using irrigation water? ....

56What is the system of water allocation?

a. Proportional to the amount of land you have under irrigation.		C. Specify if any other system	
b. Equal division among members of the association			

57Does the community have a system of rule for controlling water distribution default? Yes/No

58Are there special considerations for crop-type and stage of growth during water allocation?Yes/No

F) Sustainability of the project

59Do you feel that the irrigation scheme belongs to you? Yes/No

60. If No, whom do you think it belongs to?

a. to the community		c. to the NGOs	
b. to the government		d. Any combination of the above	

61Have you ever participated in maintenance of the irrigation scheme? Yes/No

62. If you do not make the maintenance, what is the reason?

a. It is not my responsibility		c. Others (specify)	
b. I do not know how to do it			

Appendix-2 Table

Appendix Table 2.1 Average measured discharge data at main canal

Monitoring location: south gonderestie

Date 15/08/09
Main intake

Gps Data

X	Y	Z
393754	1278220	2384

Trial	width(w)	Waterdep,cm	at 0.6d	revolution	N(revolution/sec)	A(m2)	v(cm/s)	v(m/s)	Q(m3/s)	Q avg (l/s)
1	0.7	0.7	0.42	15	0.25	0.49	9.72	0.10	0.048	48.5
2	0.7	0.7	0.42	16	0.27	0.49	10.24	0.10	0.050	
3	0.7	0.7	0.42	15	0.25	0.49	9.72	0.10	0.048	
Main intake to Mc head		X: 393678	Y: 1278185	Z: 2372						
1	0.7	0.6	0.36	12	0.20	0.42	8.16	0.08	0.034	41.0
2	0.7	0.6	0.36	24	0.40	0.42	14.40	0.14	0.060	
3	0.7	0.5	0.35	24	0.40	0.315	14.40	0.14	0.045	
4	0.7	0.45	0.315	15	0.25	0.245	9.72	0.10	0.024	
MC head to middle		X: 393829	Y: 1278269	Z: 2374						
1	0.7	0.42	0.252	20	0.33	0.294	12.32	0.12	0.036	35.2
2	0.7	0.42	0.252	19	0.32	0.294	11.80	0.12	0.035	
3	0.7	0.4	0.24	18	0.30	0.28	11.28	0.11	0.032	
4	0.7	0.4	0.24	21	0.35	0.28	12.84	0.13	0.036	
5	0.7	0.4	0.24	22	0.37	0.28	13.36	0.13	0.037	
MC Middle to Tail		X: 393873	Y: 1278283	Z: 2373						
1	0.7	0.4	0.24	22	0.37	0.21	13.36	0.13	0.028	26.2
2	0.7	0.3	0.18	19	0.32	0.21	11.80	0.12	0.025	
3	0.7	0.3	0.18	20	0.33	0.21	12.32	0.12	0.026	

Appendix Table 2.2 Average measured discharge data at secondary canal

Secondary canal(sc1) Upper										
Trial	width (w)	Water dep., cm	at 0.6d	revolution	N(revolution/sec	A(m2)	v(cm/s)	v(m/s)	Q(m3/s	Q avg (l/s)
1	0.40	0.45	0.27	14.00	0.47	0.18	16.48	0.16	0.03	25.70
2	0.40	0.40	0.24	14.00	0.47	0.16	16.48	0.16	0.03	
3	0.39	0.35	0.21	13.00	0.43	0.14	15.44	0.15	0.02	
	secondary canal(Sc1) lower									
1	0.39	0.30	0.18	11.00	0.37	0.12	13.36	0.13	0.02	15.60
2	0.39	0.30	0.18	12.00	0.40	0.12	14.40	0.14	0.02	
3	0.38	0.28	0.17	12.00	0.40	0.11	14.40	0.14	0.02	
4	0.39	0.28	0.17	11.00	0.37	0.11	13.36	0.13	0.01	
	Secondary canal(sc2) Upper									
1	0.35	0.26	0.16	21.00	0.70	0.09	23.75	0.24	0.02	18.28
2	0.32	0.23	0.14	22.00	0.73	0.07	24.79	0.25	0.02	
3	0.30	0.22	0.13	20.00	0.67	0.07	22.71	0.23	0.01	
Secondary canal (sc2) lower										
1	0.3	0.2	0.1	16.0	0.53	0.07	18.55	0.19	0.01	11.03
2	0.3	0.2	0.1	15.0	0.50	0.06	17.52	0.18	0.01	
3	0.3	0.2	0.1	15.0	0.50	0.06	17.52	0.18	0.01	

Appendix Table 2.3 before and after irrigation soil moisture Original data.

Location	Depth	W1 (g)	Before irrigation weight of can & soil		After irrigation weight of can & soil		Before irrigation weight of can & soil		After irrigation weight of can & soil		Before irrigation weight of can & soil		After irrigation weight of can & soil	
			W2 (g)	W3 (g)	W2 (g)	W3 (g)	W2 (g)	W3 (g)	W2 (g)	W3 (g)	W2 (g)	W3 (g)	W2 (g)	W3 (g)
H	0-30	37.4	119	97.41	154	121	165	149	158	135	162	134.	155	124
	30-60	37.5	134.2	106.9	161	123	177	152	156	130	162	139	152.5	127.4
	60-90	37.7	136.9	107.4	150.0	112	172	144	163	135	153	135	157.3	131
M	0-30	35.9	111.6	91.0	187	145	199	160	178	138	170	155	171.5	147
	30-60	35.8	221	180	190	154	182	146	176	133	173	146	171	139.8
	60-90	35.8	128.9	105.2	191	146	170	132	195	144	170	147	180	150.3
T	0-30	35.8	130.5	100.2	208	147	189	161	215	178	166	156	179	158.3
	30-60	36	111.9	90.8	158	135	165	141	175	133.5	175	148	178.5	139.4
	60-90	35.9	134	105.3	165.2	119.	172	150	164	137.8	171	142	195	161

Where :-Weight of container, W1 (g), Weight of container +wet soil, W2 (g)

Weight of container + dry soil, W3 (g) Weight of moisture soil (W2-W3) g

Weight of dry soil (W3-W1) g

Moisture water content $W=\frac{(W2-W3)}{(W3-W1)}\times100$

Appendix Table 2.4Average soil moisture content before and after irrigation

	Depth	Initial		Development		Mid-season				
Sampling location		Bi(%)	Ai(%)	Bi (%)	Ai (%)	Bi (%)	Ai (%)	Average Bi (%)	Average Ai (%)	Bulk density
Head	0-30	36.0	39.47	14.3	23.6	28.7	35.8	26.2	32.9	1.01
	30-60	39.3	44.44	21.8	28.1	22.7	27.9	27.8	33.5	1.35
	60-90	42.4	51.40	26.3	28.8	19.1	28.1	29.3	36.1	1.44
Middle	0-30	37.2	38.50	31.4	39.2	13.1	22.1	27.2	33.2	1.02
	30-60	28.4	30.46	32.7	44.2	24.7	30.0	28.6	34.9	1.35
	60-90	34.1	40.83	39.5	47.1	20.7	26.0	31.4	38.0	1.43
Tail	0-30	47.0	54.86	22.4	26.0	8.3	16.9	25.9	32.6	1.03
	30-60	38.4	23.23	22.9	42.6	24.3	37.8	28.5	34.5	1.35
	60-90	42.7	55.38	19.3	25.8	27.9	27.2	30.0	36.1	1.44

Bi and Ai are moisture contents before and after irrigation

Appendix Table 2.5: Total moistureStored depth, (mm).

Soil sample	Soil depth (cm)	BUlk density (gm/cm3)	Time of sampling		Moisture Content (%)	Moisture stored (mm)	Total Moisture stored (mm)
			before irrigation	after irrigation			
Head	`0-30	1.01	26.2	32.9	6.7	20.29	78.02
	30-60	1.35	27.8	34.8	7.0	28.39	
	60-90	1.44	29.3	36.1	6.8	29.33	
Middle	`0-30	1.02	27.2	33.3	6.1	18.51	72.69
	30-60	1.35	28.6	34.9	6.4	25.68	
	60-90	1.43	31.4	38.0	6.7	28.50	
Tail	`0-30	1.03	25.9	32.6	6.7	19.61	71.43
	30-60	1.35	28.5	34.5	6.0	23.44	
	60-90	1.44	30.0	36.1	6.2	26.66	

Appendix Table 2.6: Average soil moisture content at field capacity and permanent welting point

Soil sample	Soil depth (cm)	BUlk density (gm/cm3)	FC (%)	PWP%	(FC (%)-PWP%	Required depth (Wn)mm
Head	`0-30	1.01	40.06	24.61	46.88	84.45
	30-60	1.35	36.93	29.96	28.22	
	60-90	1.44	34.05	31.88	9.35	
Middle	`0-30	1.02	39.43	27.14	37.51	
	30-60	1.35	34.96	27.85	28.74	74.87
	60-90	1.43	30.67	28.66	8.62	
Tail	`0-30	1.03	40.43	28.52	36.73	75.64
	30-60	1.35	35.2	28.90	25.50	
	60-90	1.44	31.63	28.53	13.42	

Appendix Table 2.7: CurrentCondition of irrigation structures on the irrigation scheme

Status of existing structures in number					
No	Types of structure	Initially installed	Operative	Nearly operative	In operative
1	Drop structure	55	13	19	23
2	Division box	9	1	4	4
3	Sheet metal flume	1	1	.	.
4	Cross drainage Culvert	1	..	1	…
5	Inverted siphon	3	1		2
6	A wooden bridge	6	1	2	3
7	Drop with turnout	10	3	1	6
8	Intake gate	1		1	
Total		86	20	28	38
Effectiveness of infrastructure (%)			23.25	32.55	44.2

Note: Operative structure means that the structure can currently perform its basic design, function and displays no signs of losing its' capacity around a year, a nearly operative structure is one that is reflected likely to become functional, but incapable to achieve its full basic function about a year, whereas, inoperative structure found that any was unable to perform its basic function at the time of the investigation.

Appendix Table 2.8: Discharge characteristics of Parshall flumes

Throat width b_c in feet or inches	Discharge range in $m^3/s \times 10^{-3}$		Equation $Q = K h_a^u$ (Q in m^3/s)	Head range in metres		Modular limit h_b/h_a
	minimum	maximum		minimum	maximum	
1″	0.09	5.4	$0.0604 h_a^{1.55}$	0.015	0.21	0.50
2″	0.18	13.2	$0.1207 h_a^{1.55}$	0.015	0.24	0.50
3″	0.77	32.1	$0.1771 h_a^{1.55}$	0.03	0.33	0.50
6″	1.50	111	$0.3812 h_a^{1.58}$	0.03	0.45	0.60
9″	2.50	251	$0.5354 h_a^{1.53}$	0.03	0.61	0.60
1′	3.32	457	$0.6909 h_a^{1.522}$	0.03	0.76	0.70
1′6″	4.80	695	$1.056 h_a^{1.538}$	0.03	0.76	0.70
2′	12.1	937	$1.428 h_a^{1.550}$	0.046	0.76	0.70
3′	17.6	1427	$2.184 h_a^{1.566}$	0.046	0.76	0.70
4′	35.8	1923	$2.953 h_a^{1.578}$	0.06	0.76	0.70
5′	44.1	2424	$3.732 h_a^{1.587}$	0.06	0.76	0.70
6′	74.1	2929	$4.519 h_a^{1.595}$	0.076	0.76	0.70
7′	85.8	3438	$5.312 h_a^{1.601}$	0.076	0.76	0.70
8′	97.2	3949	$6.112 h_a^{1.607}$	0.076	0.76	0.70
	in m^3/s					

Appendix 2:9 Monthly rainfall (mm) data at Estie meteorology station from 1994 to 2016

MO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	P(mm)/year
1994	5.9	7.4	42.2	51.2	69.0	212.4	356.6	295.3	219.0	18.2	30.0	2.3	1309.5
1995	0.0	0.0	26.1	68.8	102.4	44.5	296.5	222.9	133.0	0.2	7.2	24.2	925.8
1996	20.3	12.5	83.9	79.8	124.5	183.9	511.5	345.2	257.5	19.6	32.0	5.4	1676.1
1997	0.3	0.0	79.6	32.6	99.9	176.1	363.3	351.6	129.2	102.5	100.2	5.6	1440.9
1998	2.9	0.0	35.1	16.9	75.3	265.0	301.1	262.5	249.2	100.0	1.2	0.0	1309.2
1999	24.3	0.0	0.0	72.2	24.4	125.8	365.0	349.5	184.6	193.5	7.9	30.8	1378.0
2000	0.0	0.0	26.9	67.4	40.2	183.3	426.7	279.2	143.1	145.2	73.0	27.7	1412.7
2001	0.0	4.7	52.2	79.3	58.8	260.5	377.0	401.9	64.9	73.6	0.0	12.1	1385.0
2002	3.8	1.2	52.1	34.5	5.8	191.1	344.3	362.8	207.1	14.6	3.2	3.6	1224.1
2003	0.0	16.5	76.8	6.3	10.7	168.6	379.2	316.4	237.2	16.5	3.7	20.7	1252.6
2004	5.2	8.3	11.2	57.7	23.2	132.2	415.1	194.2	103.1	44.7	22.3	2.4	1019.6
2005	3.9	3.6	56.6	12.9	35.8	115.8	330.2	257.1	167.8	39.8	41.3	0.0	1064.8
2006	0.0	2.9	16.5	42.2	125.1	257.4	310.8	277.2	167.8	82.8	41.3	21.4	1345.4
2007	20.6	11.1	47.9	42.9	78.9	338.9	308.5	284.3	163.3	36.7	68.1	0.0	1401.2
2008	6.4	5.0	0.0	70.2	178.3	204.3	330.0	304.0	107.4	95.4	15.4	0.2	1316.6
2009	0.0	26.4	56.4	11.8	26.5	212.3	442.3	253.8	81.3	108.6	28.8	15.0	1263.2
2010	22.0	0.0	29.1	62.6	72.2	174.9	515.6	322.7	171.3	77.6	39.3	22.0	1509.4
2011	33.9	11.2	41.0	45.3	75.7	209.6	357.6	282.5	165.2	75.1	19.4	9.8	1326.3
2012	0.0	7.5	37.4	46.5	65.7	193.6	355.0	271.8	152.2	65.7	20.9	9.8	1226.0
2013	2.7	0.0	13.4	20.4	73.4	184.5	456.5	305.3	130.8	144.0	57.5	0.4	1388.9
2014	0.0	4.3	42.3	71.9	74.7	154.1	255.1	305.1	130.8	84.1	33.7	9.1	1165.1
2015	1.3	2.7	45.4	8.6	252.8	146.8	315.4	353.4	205.7	29.0	30.5	33.5	1425.1
2016	0.0	0.9	15.1	12.2	145.6	216.8	305.8	418.3	132.5	61.5	0.0	0.0	1308.7
Aver	6.7	5.5	38.6	44.1	80.0	189.2	366.0	305.1	161.0	70.8	29.4	11.1	1307.6

Appendix Table 2.10.Monthely mean minimum temperature (^{0}c) from 1994-2016

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1994	4.9	6.4	8.5	10.0	10.4	10.6	11.1	12.3	7.9	7.8	5.9	4.6
1995	3.8	6.9	7.1	10.3	11.4	10.4	11.8	11.3	9.2	5.9	5.4	6.0
1996	4.5	4.7	8.5	10.2	8.8	10.0	10.2	10.3	9.1	6.3	6.0	5.0
1997	5.1	5.1	9.4	8.7	10.4	10.6	11.4	10.6	8.8	8.6	8.5	6.0
1998	6.2	6.4	9.3	10.3	11.1	10.2	11.7	12.0	10.3	9.3	4.3	2.1
1999	4.5	5.4	5.9	9.6	10.0	10.0	10.8	10.9	8.6	8.8	3.8	4.3
2000	3.6	4.6	7.0	9.6	9.5	10.2	10.6	10.6	8.8	9.4	6.3	4.3
2001	2.7	6.6	8.3	9.7	10.3	10.8	11.4	11.4	10.2	8.9	5.0	5.5
2002	5.8	7.6	9.0	9.7	10.4	11.2	10.3	10.6	8.6	6.5	6.3	5.8
2003	5.0	8.2	10.0	9.7	10.9	10.8	11.3	11.1	8.4	6.3	4.7	4.1
2004	5.4	6.1	8.7	11.0	9.4	10.9	9.7	10.9	9.2	6.1	5.8	5.4
2005	4.5	6.9	9.6	10.8	10.1	10.8	10.8	11.0	9.2	8.1	5.9	2.0
2006	4.5	7.1	8.7	9.9	10.5	10.2	11.4	11.2	9.4	9.2	7.7	5.8
2007	6.3	7.6	8.7	10.5	11.2	11.0	12.5	11.2	10.1	11.7	4.7	2.3
2008	6.0	6.2	5.8	9.7	10.5	10.7	10.4	10.8	9.5	8.0	5.6	4.5
2009	4.1	8.2	9.1	9.7	10.4	10.2	11.5	11.6	8.7	7.9	4.9	6.4
2010	5.6	7.9	8.7	11.4	10.4	11.3	11.2	11.7	9.2	7.7	5.8	4.5
2011	6.1	4.4	8.5	9.9	10.8	10.6	10.6	11.4	9.7	6.6	7.6	4.6
2012	4.3	6.4	8.4	10.0	10.3	10.6	11.0	11.2	9.2	7.6	5.6	4.8
2013	5.0	6.9	9.1	9.0	10.9	11.1	10.7	11.1	9.3	8.2	7.1	3.3
2014	5.7	5.4	9.2	10.6	10.4	10.1	11.7	10.8	9.6	8.3	6.7	4.4
2015	4.1	7.6	9.0	9.8	11.5	11.1	9.8	11.2	9.2	8.9	7.3	9.2
2016	5.4	7.3	10.6	11.0	12.0	11.7	11.8	11.7	10.6	9.3	4.8	4.7
Average	**4.9**	**6.5**	**8.6**	**10.1**	**10.5**	**10.7**	**11.0**	**11.2**	**9.3**	**8.0**	**5.9**	**4.8**

Appendix Table 2.11.Monthely mean maximum temperature (^{0}c) from 1994-2016

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1994	27.7	29.3	28.7	28.6	26.1	23.4	20.0	21.4	23.0	25.6	26.5	27.0
1995	27.4	28.0	27.6	26.4	26.1	25.9	20.5	22.0	24.0	27.5	28.1	26.0
1996	26.6	29.1	27.8	26.4	25.2	22.7	21.4	22.3	24.1	26.6	26.0	26.3
1997	26.9	28.9	28.4	27.1	26.9	24.6	22.4	23.7	25.7	26.3	26.4	27.4
1998	27.8	28.2	29.7	30.2	27.7	24.4	20.8	22.2	25.3	26.4	28.1	27.6
1999	27.1	30.0	29.4	29.3	27.5	25.8	20.9	22.4	25.0	26.0	29.6	28.3
2000	29.2	30.6	30.7	27.9	28.9	24.8	22.8	22.7	24.9	25.6	27.1	27.5
2001	27.9	29.9	27.8	29.0	27.3	23.0	21.8	21.7	24.1	25.9	26.5	27.3
2002	27.2	29.7	29.3	29.8	29.5	25.0	23.0	22.4	23.3	26.3	28.2	27.8
2003	28.6	29.8	28.3	29.5	29.8	25.1	21.7	22.2	23.6	27.3	29.4	28.5
2004	29.1	29.8	30.4	27.9	29.5	24.7	22.6	22.8	24.2	27.1	28.4	28.6
2005	27.9	31.0	29.4	29.4	27.7	26.0	21.6	23.2	23.6	26.8	26.5	27.5
2006	28.7	29.9	29.2	28.7	26.5	23.8	22.0	21.9	23.2	25.9	26.5	26.4
2007	26.6	28.4	29.7	28.0	27.4	23.1	21.6	22.3	23.9	27.0	27.1	27.6
2008	28.2	28.8	30.6	28.2	26.1	23.6	22.4	22.7	24.2	25.3	25.6	25.9
2009	27.9	28.8	29.2	29.6	29.4	27.3	22.1	22.7	24.5	26.1	27.7	26.7
2010	27.4	28.9	28.8	28.5	26.9	24.6	21.5	22.1	23.8	26.2	26.2	25.2
2011	26.3	29.1	21.1	29.7	26.4	24.5	22.0	22.0	23.0	26.5	25.5	26.6
2012	27.9	29.1	27.2	28.6	27.5	24.6	21.7	22.4	24.1	26.4	27.2	27.2
2013	28.0	29.9	29.4	30.4	28.0	24.4	21.0	20.9	23.6	24.6	26.1	26.1
2014	27.4	28.4	28.1	28.1	27.3	24.5	22.3	22.4	23.7	25.7	27.2	26.9
2015	27.8	22.9	29.4	27.7	24.1	22.4	23.0	22.7	23.8	26.0	22.2	24.9
2016	26.2	27.5	30.5	29.2	25.3	24.6	21.8	21.8	23.1	24.8	25.5	25.3
Average	**27.6**	**29.0**	**28.7**	**28.6**	**27.3**	**24.5**	**21.8**	**22.3**	**24.0**	**26.2**	**26.9**	**26.9**

Appendix 2.12: Average 22 Years (1994-2016) Climatic Data Estie Station and ETo.

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\Msc climate dat\E...

Country: ethiopia   Station: Estie

Altitude: 2374 m.   Latitude: 38.05 °N   Longitude: 11.60 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	4.9	27.7	42	93	8.7	11.5	1.90
February	6.5	29.3	38	108	8.8	14.3	2.87
March	8.6	28.6	38	106	7.4	16.0	3.56
April	10.1	28.6	44	116	7.4	18.8	4.33
May	10.5	27.5	51	113	6.4	19.0	4.42
June	10.7	24.6	70	113	6.2	19.3	4.04
July	11.0	21.7	81	119	4.6	16.7	3.26
August	11.2	22.3	90	106	4.7	15.6	2.88
September	9.3	24.0	74	92	6.5	15.7	2.94
October	8.0	26.2	62	81	7.8	14.1	2.52
November	5.9	27.1	64	79	7.9	11.3	1.83
December	4.8	27.1	48	83	8.5	10.5	1.56
Average	**8.5**	**26.2**	**59**	**101**	**7.1**	**15.2**	**3.01**

Appendix 2.13: Mean Monthly Rainfall and Effective Rainfall (USDA SCS method) forGomit small scale Irrigation Scheme

Monthly rain - C:\ProgramData\CROPWAT\data\rain\MSC.CRM

Station: Estie   Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	6.7	6.6
February	5.5	5.5
March	38.6	36.2
April	44.1	41.0
May	80.0	69.8
June	189.2	131.9
July	366.0	161.6
August	305.1	155.5
September	161.0	119.5
October	70.8	62.8
November	29.4	28.0
December	11.1	10.9
Total	**1307.5**	**829.3**

Appendix 2.14: CROPWAT 8 Output for Garlic Water Requirement

Crop Water Requirements

ETo station: Estie | Crop: Gralic

Rain station: Estie | Planting date: 01/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.70	1.16	11.6	5.2	6.4
Dec	2	Deve	0.72	1.12	11.2	3.1	8.2
Dec	3	Deve	0.84	1.41	15.5	2.8	12.8
Jan	1	Mid	0.98	1.75	17.5	2.6	14.9
Jan	2	Mid	1.02	1.95	19.5	2.1	17.4
Jan	3	Mid	1.02	2.28	25.1	2.0	23.1
Feb	1	Mid	1.02	2.61	26.1	0.9	25.1
Feb	2	Mid	1.02	2.94	29.4	0.3	29.1
Feb	3	Mid	1.02	3.17	25.4	4.2	21.2
Mar	1	Mid	1.02	3.41	34.1	9.5	24.7
Mar	2	Late	1.01	3.60	36.0	13.3	22.7
Mar	3	Late	0.93	3.54	38.9	13.4	25.5
Apr	1	Late	0.83	3.40	34.0	12.4	21.6
Apr	2	Late	0.75	3.25	29.3	11.3	16.7
					353.6	**83.1**	**269.3**

Appendix 2.16: CROPWAT 8 Output for MaizeIrrigation Water Requirement

Crop Water Requirements

ETo station: Estie | Crop: maiz

Rain station: Estie | Planting date: 15/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	2	Init	0.70	1.09	6.6	1.9	5.0
Dec	3	Init	0.70	1.17	12.9	2.8	10.1
Jan	1	Deve	0.70	1.26	12.6	2.6	10.0
Jan	2	Deve	0.80	1.52	15.2	2.1	13.1
Jan	3	Deve	0.94	2.09	23.0	2.0	21.0
Feb	1	Deve	1.08	2.75	27.5	0.9	26.6
Feb	2	Mid	1.21	3.46	34.6	0.3	34.3
Feb	3	Mid	1.23	3.83	30.6	4.2	26.4
Mar	1	Mid	1.23	4.11	41.1	9.5	31.7
Mar	2	Mid	1.23	4.40	44.0	13.3	30.7
Mar	3	Mid	1.23	4.71	51.9	13.4	38.5
Apr	1	Late	1.18	4.80	48.0	12.4	35.6
Apr	2	Late	0.98	4.25	42.5	12.6	29.9
Apr	3	Late	0.78	3.38	33.8	16.1	17.7
May	1	Late	0.64	2.82	8.5	5.7	0.0
					432.8	**99.8**	**330.5**

Appendix 2.17: CROPWAT 8 Output for OnionIrrigation Water Requirement

Crop Water Requirements

ETo station: Estie | Crop: Onion

Rain station: Estie | Planting date: 25/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	3	Init	0.70	1.17	8.2	1.8	6.8
Jan	1	Init	0.70	1.25	12.5	2.6	9.9
Jan	2	Deve	0.72	1.38	13.8	2.1	11.7
Jan	3	Deve	0.81	1.79	19.7	2.0	17.7
Feb	1	Deve	0.89	2.27	22.7	0.9	21.8
Feb	2	Deve	0.97	2.80	28.0	0.3	27.6
Feb	3	Mid	1.05	3.25	26.0	4.2	21.7
Mar	1	Mid	1.07	3.56	35.6	9.5	26.1
Mar	2	Mid	1.07	3.81	38.1	13.3	24.8
Mar	3	Mid	1.07	4.08	44.9	13.4	31.5
Apr	1	Late	1.03	4.18	41.8	12.4	29.4
Apr	2	Late	0.88	3.81	38.1	12.6	25.5
Apr	3	Late	0.78	3.40	10.2	4.8	2.1
					339.6	**79.9**	**256.8**

Appendix 2.18: CROPWAT 8 Output for PotatoIrrigation Water Requirement

Crop Water Requirements

ETo station: Estie | Crop: potato

Rain station: Estie | Planting date: 20/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	2	Init	0.50	0.78	0.8	0.3	0.8
Dec	3	Init	0.50	0.84	9.2	2.8	6.4
Jan	1	Deve	0.60	1.07	10.7	2.6	8.0
Jan	2	Deve	0.93	1.76	17.6	2.1	15.5
Jan	3	Mid	1.17	2.61	28.7	2.0	26.7
Feb	1	Mid	1.18	3.01	30.1	0.9	29.1
Feb	2	Mid	1.18	3.39	33.9	0.3	33.6
Feb	3	Mid	1.18	3.66	29.3	4.2	25.0
Mar	1	Late	1.18	3.93	39.3	9.5	29.8
Mar	2	Late	1.07	3.81	38.1	13.3	24.8
Mar	3	Late	0.89	3.40	37.4	13.4	24.0
Apr	1	Late	0.73	2.97	23.8	9.9	11.4
					298.8	**61.4**	**235.2**

Appendix 2.19: CROPWAT 8 Output for TomatoIrrigationWater Requirement

Crop Water Requirements

ETo station: Estie | Crop: tomato

Rain station: Estie | Planting date: 01/12

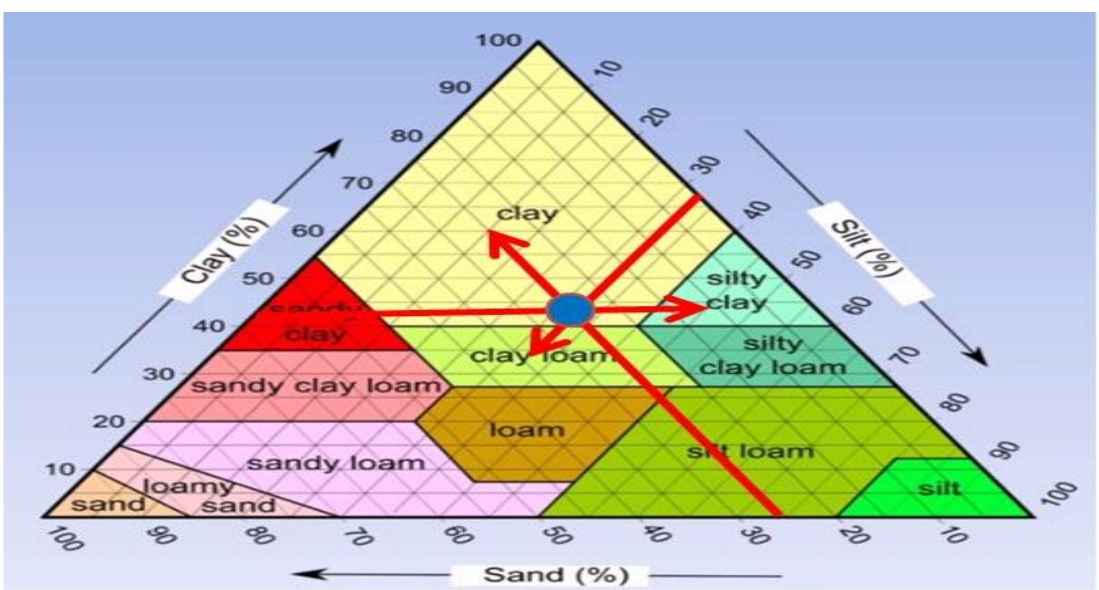
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.60	0.99	9.9	5.2	4.8
Dec	2	Deve	0.63	0.98	9.8	3.1	6.7
Dec	3	Deve	0.81	1.36	15.0	2.8	12.2
Jan	1	Mid	1.01	1.81	18.1	2.6	15.5
Jan	2	Mid	1.08	2.06	20.6	2.1	18.5
Jan	3	Mid	1.08	2.41	26.5	2.0	24.5
Feb	1	Mid	1.08	2.76	27.6	0.9	26.6
Feb	2	Late	1.08	3.09	30.9	0.3	30.6
Feb	3	Late	0.97	3.00	24.0	4.2	19.7
Mar	1	Late	0.81	2.69	26.9	9.5	17.4
					209.3	**32.7**	**176.5**

Appendix 2.20: Net scheme Irrigation requirement at Gomit small scale irrigation scheme

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Gralic	28.4	70	77.5	89	37	0	0	0	0	0	0	0
2. maiz	22.1	58	92.8	117	64	0	0	0	0	0	0	0
3. Onion	9.9	53	70.7	96	45	0	0	0	0	0	0	0
4. potato	11.2	65	95	93	10	0	0	0	0	0	0	0
5. tomato	35.9	78	80.2	21	0	0	0	0	0	0	0	0
Net scheme irr.req.												
in mm/day	0.7	2.3	2.7	**2.9**	1.1	0	0	0	0	0	0	0
in mm/month	22	66	82.5	88	33	0	0	0	0	0	0	0
in l/s/h	0.08	0.3	0.31	0.3	0.1	0	0	0	0	0	0	0
Irrigated area(% of total area	100	100	100	100	90	0	0	0	0	0	0	0
Irr.req. for actual area (l/s/h)	0.08	0.3	0.31	0.3	0.1	0	0	0	0	0	0	0

Appendix-3 Figure

Appendix figure -3.1 Soil sampling method



Appendix figure 3.2 Determination Soil Textural class

Appendix figure 3.3Lined canal filled by sediment due to poor management of canal

Appendix figure 3.4unfunctional drop structure.


Appendix figure 3.5 Seepage and linkage problems.


Appendix figure 3.6 highly vegetated lied canals.


Appendix figure 3.7 Good condition Lined main and secondary canal