Addis Ababa University

Addis Ababa Institute of Technology

School of Graduate Studies

Performance Evaluation of Small-Scale Irrigation Scheme:

(A case Study of Golina Small-Scale Irrigation scheme, North Wollo, Ethiopia)

A thesis submitted and presented to the school of graduate studies of Addis Ababa University in partial fulfillment of the degree of Masters of Science in Civil and Environmental Engineering (Major in Hydraulic Engineering)

By

Zinabie Mekonnen

Advisor: Dr. Daneal Fekersillassie

December, 2018

Addis Ababa, Ethiopia

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The undersigned certify that he has read the Thesis entitled Performance Evaluation of Small-Scale Irrigation Scheme:*(A case Study of Golina Small-Scale Irrigation scheme , North Wollo, Ethiopia)* and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science.

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Declaration and Copy right

I, Zinabie Mekonnen Taye, declare that this is my own original work and that it has not been presented and will not be presented to any other University for similar or any degree award and all materials used for this thesis work have been properly acknowledged.

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Dedication

I dedicated this thesis manuscript to my parents for their support throughout the day to day activity for my activities. Generally to all my beloved families and friends who were with me for the success of the work.

Abstract

Performance evaluation of irrigation system is essential to assess how far the goals and objectives set forth at the time of project formulation of the system have been achieved. Efficient operation and management for small scale irrigation system plays an important role in the sustainability of irrigated agriculture. Nowadays, non-uniform water distribution among upstream and downstream users, structural failure, sedimentation and growing of weeds are the characteristics of Golina small-scale irrigation scheme. This study was initiated to evaluate the performance of Golina small-scale irrigation scheme using efficiency indicator, maintenance indicator and farmers perception. Primary data (discharge measurements in the canals, measurement of water applied to the farmers' field, field observations, interviewing beneficiary farmers, and determination of moisture contents of the soil before and after irrigation, determination of soil physical properties) and secondary data like design document and number of farmers were collected to conduct this study. This study was conducted for one irrigation season (February-May). The collected data were analyzed using empirical equations and statistical analysis in percentage basis. The application efficiency result on three sample plots in farmers' field located at Head, middle and tail reaches of the command area were found to be 46.30%, 65.87% and 76.07% respectively. Based on the maintenance indicator analysis, the main canal transports 82% of its design capacity. The effectiveness of infrastructures is found that 38.36% of initially installed structures were non-functional. The sustainability of irrigated area of the scheme was decreased by 35.14% compared with the planned area. Based on the assessment of farmer's perception about the performance of the irrigation scheme, the respondents believe that major problems that make the scheme to be inefficient were maintenance problem, water theft or unauthorized canal breaching in the scheme, water shortage and water utilization conflict and they have low level of ownership of the scheme. Generally the overall performance of the scheme is considered as poor. So, it is important to strength water user association, provide hydraulic flow measurements, routine maintenance and creating awareness for the users to achieve good performance of the scheme.

Key words: Golina, Performance, Efficiency, Maintenance, Applied depth.

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Abbreviations

AAiT	Addis Ababa Institute of Technology
ADSWE	Amhara design and supervision works enterprise
ANRS	Amhara National Regional State
BD	Bulk density
Cm	Centimeter
Cm^3	Cubic Centimeter
D_{req}	Depth required
DU	Distribution Uniformity
Ds	Depth stored
Ea	Application Efficiency
Ec	Conveyance efficiency
E.g.	For Example
EPCC	Ethiopian Panel on Climate Change
Es	Storage Efficiency
FAO	Food and Agricultural Organization
FC	Field Capacity
Gm	Gram
GOs	Governmental Organizations
GPS	Global Positioning System
Ha	Hectare
ICID	International Commission on Irrigation and Drainage
ILRI	International Livestock Research Institute
IWMI	International Water Management Institute
L	Liter
M	Meter
M^2	Square meter
M.a.s.l	Meter above sea level
MM	Millimeter

M^3	Cubic Meter
MC	Main Canal
MoARD	Ministry of Agriculture and Rural Development
MoWR	Ministry of Water Resources
NGOs	Non-Governmental Organizations
PWP	Permanent Wilting Point
Q	Discharge
S	Second
SARC	Sirinka Agricultural Research Center
SC	Secondary Canal
SCEE	School of Civil and Environmental Engineering
SCS	Soil Conservation Service
T	Time
TAW	Total Available Water
USDA	United State Department of Agriculture
USAID	United State Agricultural and International Development
US	United State
UTM	Universal Transversal Mercator
WSE	Water surface elevation
Zr	Root depth
^oC	Degree Celsius
%	Percent

1. INTRODUCTION

1.1. Background

Many countries are expected to face insufficient water resources satisfy their current agricultural, domestic, industrial and environmental water demands within the next two decades. The world population is forecasted to grow by about 30% by the year 2025, reaching 8billion people. As a results of improved communications, globalization and more urbanization, the living standards of the people are expected to increase. This means competition among the agricultural, industrial, domestic and other users will increase in unprecedented levels (FAO, 2011).

Irrigation is an agricultural activity that delivers water to fill the soil moisture deficit. For the farmers, it is a component of successful crop husbandry particularly in a dry climate. A consistent and appropriate irrigation water supply can result in enhancements in agricultural production and assure the economic vitality. Many civilizations have risen on irrigated agriculture. These provide basis for their society and enhance food security of their people. Some have estimated that as little as 15-20% of the worldwide total cultivated area is irrigated (FAO, 1989). Irrigation can be defined as the science of artificial application of water to the land in accordance with the crop requirement through the cropping period for full-fledge nourishment of the crops (Eticha, 2011).

The utilization of important resources in irrigated agriculture is very important for sustainable production of irrigated agricultures. The potential efficiency of the system evaluated by on-farm operations. Performance assessment has been an essential part of irrigation since man first started harnessing water to improve crop production. Evaluation involves measuring conditions at one or more points in a field selected to be typical or representative for the irrigation projects (Pereira and Trout, 1999).

Ethiopia is one of few African countries endowed with abundant water resources. The country has 12 river basins with an annual runoff volume of 124billion cubic meter of water and an estimated ranges of 2.6 to 30billion cubic meter ground water potential (EPCC, 2015). The irrigation potential is also estimated about 5.3million ha from 15million ha of total cultivated area.

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

Nevertheless, Ethiopian irrigation projects, in most cases, have failed to significantly enhance the livelihoods of rural communities or substantially impact food security. The World Bank, various development agencies and numerous countries have invested in large irrigation projects, but there is disagreement on whether investing in new irrigation projects is appropriate because of the less than satisfactory performance of existing projects(Burt and Styles, 1999). Most of the government initiated and community-managed projects are confronted with multifaceted technical and socio economic problems, which have resulted in low land, water and labor productivity.

Agriculture is regarded as the backbone of Ethiopian economy and a key driver of its long term growth and food security. Agriculture directly supports 85% of the population constitutes. Of which 43% of gross domestic product, and 80% of export value (Awulachew *et al.*, 2010a). Agriculture employs 80% of the labor force while 85% of the population, which currently is above one hundred million, depends on agriculture for a living and live in rural areas (Awulachew, 2006).

Amhara region is one of the regions which have abundant water resources in Ethiopia. The annual runoff in the region is estimated to be 60billion cubic meter with water resources per capital of 3,570 cubic meter (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 - 700,000ha and for small scale irrigation is about 200,000 - 250,000ha, indicates the magnitude of water resources available for development (Bceom, 1999).

Small scale irrigation structures, owing to their relatively small investment cost, encase of construction, simplicity of operation and maintenance has been a strategic target of the country for achieving sustainable food security and self-sufficiency. A number of such schemes have been designed and constructed in the previous years.

However, while some schemes are performing successfully, it has been observed in various reports that most of the schemes have failed to serve the purpose efficiently for which they are intended.

The exploitation and utilization of water for irrigation requires periodic evaluations of its utility and efficiency.

This concern with performance within the irrigation sector is increasing as pressure grows on water resources in all parts of the world, and as concerns increase regarding the sustainability of irrigated agriculture systems (Murray-Rust and Snellen, 1993).

Performance assessment of irrigation scheme is conducted for a variety of reasons. Some of the reasons are the following. To improve scheme operations, assess progress against strategic goals, as integral part of performance-oriented management, to assess the health of a scheme, to evaluate impacts of interventions, to better understand determinants of performance, to identify constraints and to compare the performance of a scheme with others or with the same scheme over time (Molden *et al.*, 1998).

Performance evaluation in irrigation is a systematic observation, documentation and interpretation the management of an irrigation scheme. The objective performance is to ensure that the input of resources, operational schedules, intended outputs and required actions proceed as planned (Bos *et al.*, 2005).

Based on the above background, the efficiencies and the effectiveness of water use at farm-level is very essential to alleviate the current challenges caused due to inefficient operation of irrigation system and poor management of an irrigation water. Golina small-scale irrigation scheme is characterized by its problem as explained above in the background part. So, it is important to study the performance of Golina small-scale irrigation scheme in order to identify problematic areas, suggest possible recommendations and improvement of the scheme. Starting from its operation, no performance studies had been conducted in Golina small-scale irrigation scheme. Hence, this leads to study the performance evaluation of Golina small-scale irrigation scheme.

1.2. Statement of the problem

According to FAO (2006), institutions responsible for low water use efficiencies induced by area based water allocation, poor field efficiency performance and the sustainability of the irrigation scheme. But few of the institutions responsible for irrigation are adequately structured and lack of qualified personnel is another cause of poor management performance irrigation systems in Africa (FAO, 1996).

In Ethiopia, scheme performance is estimated an average of 36% below design capacity. Small scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew et al., 2010a; 2010b). Amhara region is one of the regions in Ethiopia with vast potential for irrigation development. The erratic nature of rainfall and number of population increases from time to time in the region. This have a contribution for computation of users of water resources in the region. Yakob and Melaku (2006), reported that the performance of many irrigation schemes in Amhara region is far below their potential, mainly due to inefficient irrigation water management and poor repair or rehabilitation. Failure and un-sustainability of irrigation projects in Eastern Amhara has been institutional and management deficiencies.

Golina small-scale irrigation is found in this region and characterized with erratic rainfall events. It is established for surrounding farmers who applying irrigation. Poor system management, poor understanding of farmers' priorities, lack of clear and sustainable water share among users, conflict of water users, low level of ownership of the scheme, due to lack of awareness and frequent training for water delivery and management, canals were filled with sediment and other materials before irrigation season started. Farmers spent their time in cleaning canals every season before irrigation started, the water control structures constructed in the scheme were not operational and high amount water losses in the conveyance system were the major factors.

There were no significant studies conducted regarding to performance of the scheme before this study in the irrigation scheme of Golina (study area) and in the surrounding area of the Golina small-scale irrigation scheme. This study was made to evaluate the performance of Golina small-scale irrigation scheme using indicators.

1.3. Objective of the study

1.3.1. General objective

The general objective of this study is to evaluate the performance of Golina small-scale irrigation scheme using indicators.

1.3.2. Specific objectives

- ✓ To quantify the efficiency of the irrigation scheme
- ✓ To determine maintenance indicators of the scheme
- ✓ To assess farmers' perception about scheme performance
- ✓ To suggest remedial measures

1.4. Research question

- ✓ Why distribution of water among users (farmers) is not uniform and conflicts are rampant from time to time and what is the current state of scheme efficiency of Golina irrigation scheme?
- ✓ Why irrigation scheme infrastructures are not functioned as they are intended or planned level?
- ✓ How farmers' perception significantly affect the performance and sustainability of modern irrigation scheme?
- ✓ How water user associations and farmers are responsible for poor management, training and rehabilitation activity of the irrigation scheme?
- ✓ How can minimize or control and improve the loss of water in the conveyance and field of the irrigation scheme in order to have good performance of the irrigation scheme?

1.5. Significance of the study

The performance evaluation of the irrigation scheme, described in this research work has a great role to address the current problems observed in the scheme and to improve future system management in the study area, and then interventions could be made to improve the functioning of the system. This study is providing information for the performance of the current irrigation schemes.

The study shall has significant contribution for further improvement and investment approaches for implementing agents (GOs, NGOs, and Research Centers). It also used as a benchmark and entry point for development works and future studies.

1.6. Scope of the study

The study was intended to evaluate the performance of Golina small-scale irrigation scheme by focusing on; internal performance indicators of irrigation scheme such as; conveyance efficiency, application efficiency, water storage efficiency, maintenance indicators and overall farmers' perception about the scheme performance. The study, finally makes a critical analysis of the issues related to irrigation system performance, and recommends the remedial measures to improve the performance. The study covered from the diversion point (weir) up to the end of the irrigation system layout.

2. LITERATURE REVIEW

2.1. General

2.1.1. Concept of performance

Performance is the degree to which a system achieves its objectives. The performance of a system represented by its measureable levels of achievements in terms of one or several parameters (Aberenethy, 1986).The performance of any irrigation system is defined as the degree of measurements to which it achieves its expected objectivity, therefore it is essential to measure and evaluate their success or failure of objectively and identifies specific areas in need of improvement (Cakmak *et al*., 2004). Performance of a system as encompassing the totality of both its activity inputs and the transformation of the inputs into intermediate and final outputs, and the effect of these activities on the system itself and on its external environment (Murray-Rust and Snellen 1993).

2.1.2. The need for performance assessment

Performance assessment for any irrigation system is essential to assess how far the goals and objectives set forth at the time of project formulation of the system have been achieved. This is a useful tool to provide necessary feedback for improving the systems management by initiating remedial measures (Raghava *et al*., 2011).

Performance assessment of irrigation can be defined as the systematic observation, documentation and interpretation of activities related to irrigated agriculture with the objective of continuous improvement (Molden *et al.,* 2007; Bos *et al.,* 2005).The ultimate purpose of performance assessment is to attain an efficient and effective use of resources by providing relevant responses to management at all levels. Therefore, it contributes the system management in determining whether the performance is satisfactory and, if not, which and where remedial actions need to be taken in order to remedy the situation.

Efficient operation and management for small scale irrigation system plays an important role in the sustainability of irrigated agriculture. Hence, irrigation project performance studies are being used with increasing frequency to encourage this objective.

Furthermore, performance analysis is an essential part of management, it is needed to target and monitor actual achievements in the operation and take appropriate actions if required.

Performance of an irrigation system could be assessed for a number of reasons, some of needs are; to assess development against strategic goals of a system, to improve operations, to evaluate impact of water delivery service on the whole performance of the agricultural sector, to recognize cost effectiveness and financial viability of the system, and for comparison of one with other irrigation systems (Molden, 1998).

Many scholars emphasized the importance of performance evaluation for an irrigation system. Much of the work to date in irrigation performance assessment has been focused on both external and internal processes of irrigation systems. These process indicators relate performance to management targets such as timing, duration, and flow rate of water, area irrigated and cropping patterns. Kloezen and Graces (1998), stated that effective irrigation management requires reliable performance assessment. Good farm irrigation management assures correct frequency of irrigations, correct application depth, uniform irrigation, minimum runoff, and minimum deep percolation except for that required for salt management, minimum erosion, and optimal return on irrigation investment.

Performance evaluation is basically to ensure all activities proceed smoothly as planned towards achieving those objectives and that system managers are alerted easily to potential threats to crop and production system performances and react in time to avoid or overcome the situation when it occurs. Specially, some of the major roles of performance assessment and evaluation are to ensure that the cropping intensity targets met, for accurate supply demand matching, water savings and to alert potential crisis event.

Evaluation of farm irrigation systems specially plays a fundamental role in improving surface irrigation, a system which is usually considered inefficient in terms of water use. Evaluation of the system provide information used to advise irrigators on how to improve their system design and/or operation, as well as information on improving design, and developing real time irrigation management decisions.

According to FAO (1989), the principal objective of evaluating surface irrigation systems is to identify management practices and system configurations that can be feasibly and effectively implemented to improve the irrigation efficiency.

An evaluation may show that higher efficiencies are possible by reducing the duration of the inflow to an interval required to apply the depth that would refill the root zone soil moisture deficit. The evaluation may also show opportunities for improving performance through changes in the field size and topography.

Evaluations are useful in a number of analyses and operations, particularly those that are essential to improve management and control. 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. The surface irrigation system is a complex and dynamic hydrologic system and, thus, the evaluation processes are important to optimize the use of water resources in this system (Walker, 1989)

2.1.3. Goals of performance assessment

Performance studies are being used increasing frequency to promote the objective of sustainability, thereby helping to improve the system operation, assess the general health of the system, evaluate the impact of intervention, diagnosis constraint, better understanding determinants of performance and compare its performance with others or with in the same system over the time(Unal *et al.*, 2003).

According to Nalbantoglu and Cakmak (2007), the most significant objective of performance assessment is to achieve an effective and efficient project performance by providing a flow of information to the project management in each stage. More importantly, if an irrigation system committed to the farmers satisfaction, it can supply more and better sustainability information. Arunkumar and Ambujam (2010), discussed that the ultimate purpose of performance assessment is to achieve an efficient and effective use of water resources.

Griffiths and Lecler (2001), state that the objectives of the performance evaluation in an irrigation system are:

- ✓ To control the system for functioning it according to farmer expectations and design specifications in terms of the amount of water applied, and to thereby provide a basis for improved irrigation scheduling.
- ✓ To fix how much variation in the amounts of water applied and whether or not the measured variation has a significant impact on crop yields, deep percolation, runoff losses, fertilizer application and usage as well as production cost.
- ✓ To determine the causes of the variation in applied water and to investigate and recommend cost effective remedial action.
- ✓ To assess whether or not the conveyance system is sized within design norms that were based on a fair balance between capital and operating costs.
- ✓ To suggest the remedial solution (recommendations) to improve on any aspects that would result in the effective use of water and energy.

2.2. Overview of irrigation development in Africa

There is an increase concern about food security, especially in sub-Sahara Africa. While the general global food supply or demand picture is relatively good, there will be worsening in food security in sub-Sahara 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).

FAO (1997), reported that global estimates indicate that irrigated agriculture produces nearly 40% of food and agriculture commodities on 17% of agricultural land. At present in Africa, about 12.2million hectares benefit from irrigation, which is equal to only about 8.5% of the cultivated land. In Sub-Sahara Africa, only about 10% of the agricultural production comes from irrigated land. Trends in irrigated land expansion over the last 30 years show that, on average, irrigation in Africa increased at a rate of 1.2% per year. However, this rate began to fall in the mid-1980s and is now below 1% per year, but varies widely from country to country. 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% of the world's food supply comes from the irrigated areas (FAO, 1995). However, the Africa continent has not been fortunate optimize its irrigation potential development.

FAO (1995), reported that the total water resources potential of Africa is 20,211 Bm3/year, out of which it uses only 3,991 Bm3/year (19.75%). Agriculture accounts for 85 percent of the water used. The total irrigated land of the continent is estimated to be about 124 million hectares.

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 research system in Africa is not strong though the challenge 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.

2.3. Irrigation development in Ethiopia

According to Fekadu *et al.,* (2000), development of small scale irrigation was encouraged to be effected by the local farmers to cope with recurrent droughts. The attempt by the government to enhance the participation of individual peasants in small scale irrigation development had been considered earlier throughout the 1970 and 1980; but the results were below expectations. Though the government has been providing irrigation infrastructure free of charge and the infrastructure development progressed well, but putting the schemes into production at optimum level was very disappointing, and in some instances only 10% of the developed areas were put into production.

The need of developing irrigation for crop production is acquiring more and more attention in Ethiopia in response to the growing demand for agricultural produce.

In general, Ethiopia receives an annual rainfall apparently adequate for food and pasture production. However, the distribution of rain varies from region to region. Much of the eastern part of the country receives very little rain while the western areas receive adequate rainfall. Production of sustainable and reliable food supply is almost impossible due to the temporal and spatial imbalance in the distribution of rainfall and the consequential non-availability of water at the required period. Sometimes, even the western highlands of the country suffer from food shortage owing to the discrepancies in the rainfall distribution (MoWR, 2001).

Attempts have been made by the government to address the food security problems through preparation of relevant agricultural development policies and programs. However, low level of water use efficiencies are among the major constraints for development as well as operation of all water sectors including irrigation (MoWR, 2002).

A better policy environment for the agricultural sector exists since March 1990: the liberalization of the economy; the encouragement of private commercial farms; the drastic reduction in public investment in state farms; the restoration of free grain trade; improvement in the role of extension agents, etc. However, the land holding of individual farmers is increasingly becoming fragmented because of the growing population. About six million private farms in Ethiopia register an average size of 0.8 hectares of arable land compared to 1.5hectares in 1979/80. Irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia (Awulachew *et al.*, 2005). A study also indicated that one of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales, through river diversion, constructing micro dams, water harvesting structures, etc. (Robel 2005). Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960 with the objective of producing industrial crops in Awash Valley. Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal irrigation schemes in the late 1950 in the upper and lower Awash Valley.

In the 1960, irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley.

The Awash Valley saw the biggest expansion in view of the water regulation afforded by the construction of the Koka dam and reservoir that regulated flows with benefits of flood control, hydropower and assured irrigation water supply. In addition, the construction of the tarmac Addis-Assab road opened the Awash Valley to ready markets in the hinterland as well as for export. Although, certain aspects of the development during the pre-Derg era have wrong doings in terms of property and land rights, there has been a remarkable emergence of irrigation development and establishment of agro-industrial centers. Currently, the government is giving more emphasis to the sub-sector by way of enhancing the food security situation in the country.

Efforts are being made to involve farmers progressively in various aspects of management of small-scale irrigation systems, starting from planning, implementation and management aspects, particularly, in water distribution and operation and maintenance to improve the performance of irrigated agriculture.

The country has developed irrigation schemes in many parts of the country at different scales. Data and information are not uniformly available to accurately know the existing irrigation schemes. While it is possible to capture the medium and large schemes data accurately, it is difficult to account for the small-scale irrigation development, particularly, the traditional irrigation development and the privately developed household-based irrigation schemes which use traditional diversions, water harvesting and ground water development(Awulachew *et al.,* 2007).

2.4. Irrigation scheme classification

Based on the Ministry of Water Resources (MoWR) classification, irrigation projects in Ethiopia are identified as large-scale irrigation if the size of command area is greater than 3,000 hectares, medium-scale if it falls in the range of 200 to 3,000 hectares and small-scale if it is covering less than 200 hectares (Awulachew et al., 2007).Based on this classification Golina irrigation project is a small-scale irrigation project.

2.5. Evaluating irrigation system and practices

Solomon (2006), Pereira and Trout (1999), describe information used to advice irrigators how to make better their system design and operation, improving design, model validation and updating, developing real time irrigation management decisions and optimization programming.

Basic field evaluation includes observation of outflow and inflow rates and volume (volume balance), topography and geometry of the field, slope, soil water requirement and storage, management procedure used by the irrigator.

According to Walker and Skogerboe (1987), the principal objective of evaluating an irrigation system is to identify alternatives that may be both effective and feasible in improving the system's performance. For instance, the evaluation may reveal that the application efficiency could be improved by limiting the duration of a given irrigation. It can also be discovered that the field length and slope requires modification for the existing system to operate more efficiently. Evaluations of surface irrigated fields yield not only data which can be used to detect problems but also information essential to achieving high levels of management and control.

As described by Merriam *et al.,* (1983), performance assessment practices are extremely important because of their central role in effective management. Dawit *et al.,* (1997), defined performance as a measure of "how close an irrigation event (scenario) is to the reference irrigation".
Performance assessments 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. The ultimate purpose of performance assessment is to achieve an efficient and effective use of resource by providing relevant feedback to the project management at all level (Molden *et al.,* 2004).

Bos *et al.*, (2000),described the objectives of performance assessment are: to upgrade management capabilities in both public and private sector irrigation and drainage projects with a view to improving the efficiency with which available resources are used. As such, the assessment should become part of the routine management procedures of the irrigation institution.

Four different purposes of performance assessment: operational, accountability, intervention and sustainability (Small and Svendsen, 1992).

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.

According to Yashima (1997), the following responsibilities of irrigation managers in irrigation performance assessment include:

- ✓ Evaluating the existing situation of irrigation performance in their system
- ✓ Identifying constraints to proper performance if the performance is not satisfactory and
- ✓ Implementing management interventions to improve the performance

2.5.1. Performance evaluation of irrigation scheme

The evaluation of surface irrigation at field level is an important aspect of both management and design of the system. Field measurements are necessary to characterize the irrigation system in terms of its most important parameters, to identify problems in its function, and to develop alternative means for improving the system (FAO, 1989).

Oad and Sampath (1995), good management is dependent upon appropriate methods and measures by which system performance can be evaluated relative to the management objectives. Hence, reliable measures of system performance are extremely important for improving irrigation policy making and management decisions. The development potential for small-scale irrigation seems attractive in view of cost effectiveness.

2.5.2. Performance gaps in irrigation system

According to Douglas and Juan (1999), there are four potential kinds of performance gaps that can occur with irrigation system.

Technological performance gap: This is when the infrastructure of an irrigation system lacks the capacity to deliver a given hydraulic performance standard. The normal solution to technology performance gap is to change the type, design or condition of physical infrastructure.

Implementation performance gap: The second type of performance gap is when a difference arises between how management procedures are supposed to be implemented and how they are actually implemented. This includes such problems as how people adjust gates, maintain canals and report information. A problem of this kind generally requires changes in procedures, supervision or training.

Achievement gap: The third kind of performance gap is the difference between management targets and actual achievements. Such problems are generally addressed either by changing the objectives (especially simplifying them) or increasing the capacity of management to achieve them- such as through increasing the resource available or reforming organizations.

Impacts of management: The fourth type of performance problem concern. This is a difference between what people think should be the ultimate effects of irrigation and what actually results. These are gaps in impact performance and include such measures as agricultural and economic profitability of irrigated agriculture, productivity per unit of water, poverty alleviation and environmental problems such as water logging and salinity. If management procedures are being followed and targets are being achieved, but ultimate impacts are not as intended, then problem is not that the managing organization has performed badly, since these effects are generally beyond its direct control. The problem is that the objectives of the organization do not produce the desired impacts. This is more a problem of policy than management.

2.5.3. General features of performance indicators

To carry out performance evaluation of irrigation scheme, a set of recognized and accepted parameters are required.

Rust and Snellen (1993), stated that performance indicators measure the value of a particular item such as field canal discharge and have to include a measure of quality as well as of quantity, and be accompanied by appropriate standards or permissible tolerances. In connection with main system performance, the authors conclude that the service provided by the system and the appropriate performance standards are greatly influenced by the design of that system.

According to James (1988), the performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed, and applied, and by the adequacy and uniformity of application in each field on the farm.

According to Yashima (1997), performance indicator is the response of the question, "How is it now?" The indicator is generally expressed as the ratio of actual performance to target performance. Using this indicator, irrigation managers will evaluate the performance achievement of their management at the initiation of performance assessment.

Bos *et al.,* (1994), mentioned that the system into several sub-system, and assessing the performance at those lower levels, helps describe system performance more effectively. A true performance indicator includes both an actual value and an intended value that enables the assessment of the amount of deviation. It is therefore desirable wherever possible to express indicators in the form of a ratio of the actually measured versus the intended situation. The well-known head-tail dimension of many irrigation systems represents a spatial analysis of a single variable: depending on the magnitude of the variation, a manager may have to decide what action to take next.

2.5.4. Properties of performance indicators

Some of the desirable attributes of performance indicators suggested by Bos (1997) are:

Scientific basis: The indicator should be based on an empirically quantified, statistically tested fundamental model of that part of the irrigation process it describes.

Quantifiable: The data needed to quantify the indicator must be available (measurable) with available technology. The measurement must be reproducible.

Reference to a target value: This is of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerance can be established for the indicator. These target values and their margin of deviation should be related the level of technology and management provide information without bias: ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain value judgments.

Ease use and cost effectiveness: Particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, cost of using indicators in terms of finance, equipment, and commitment of human resources, should be well within the agency's resources.

2.5.5. Irrigation efficiency

According to Eticha (2011), irrigation efficiencies are evaluated at scheme or on-farm level for the purpose of identifying the losses that occur in the irrigation system starting at the water abstraction point, through the conveyance system down to water application in the field, to determine the overall irrigation efficiency.

According to Michael (1997), irrigation water use efficiency is the ratio between the volumes used by plants through evapotranspiration process and the volume that reaches the irrigation plots and indicates how efficiently the available water supply being used, based on different methods of evaluation. The design of the irrigation scheme, the degree of land preparation, skill and care of the irrigator are the major 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 irrigation plots. Identifying various components and knowing what improvements can be made is essential to making the most effective use of the available water.

The most common way to express the efficiency of irrigation systems is to subdivide it into conveyance and application efficiencies. Once the conveyance and application efficiencies have been determined, the scheme irrigation efficiency can be calculated (FAO, 1989). According to FAO (1989), a scheme irrigation efficiency of 50-60% is good, below 50% is considered to be poor.

Irrigation efficiencies are evaluated at scheme or farm level for the purpose of identifying the losses that occur in the irrigation system starting at the water abstraction point, through the conveyance system down to water application in the field, to determine the overall irrigation efficiency. 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, 1977).

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.

2.5.6. Conveyance efficiency

According to Bos (1997), in irrigation systems the conveyance efficiency provides the best way of assessing whether canal maintenance is required. By tracking the change in conveyance efficiencies over time it should be possible to establish criteria that will indicate when canal cleaning or reshaping is necessary. Conveyance efficiency, which indicates the relative amount of water lost in a reach due to canal seepage and overflow, is typically used to address the objective of efficiency in irrigation and water-delivery systems.

According to James (1988), the conveyance efficiency is typically defined as the ratio between the water that reaches a field and that diverted from the irrigation water source as percentage. The conveyance efficiency mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of the canals (Brower and Heibloem 2011). In large irrigation schemes more water is lost than in small schemes, due to a longer canal system. From canals in sandy soils more water is lost than from canals in heavy clay soils. When canals are lined with bricks, plastic or concrete very little water is lost. If canals are badly maintained, bund breaks are not repaired properly and rats dig holes, a lot of water is lost.

According to Hansen *et al.,* (1980), the earliest irrigation efficiency concept for evaluating water losses was water-conveyance efficiency. Most irrigation water then came from diversions from streams or reservoirs. Losses which occurred while conveying water were often excessive. 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 evaporation and seepage. About 10 to15% of the water admitted into a canal can get lost in this way (Renault *et al.,* 2007).

Brower and Heibloem (2011), provide indicative values of the conveyance efficiency, considering the length of the canals and the soil type in which the canals are dug. Earthen canals with sand, loam, and clay soil type have 70%, 75%, and 85% efficiency respectively for 200-2000 meter length; If the canal is lined it will have 95% efficiency. These values will decrease for longer canals and increase for shorter canals.

According to Brouwer and Prins (1989), the conveyance efficiency for long unlined canal (>2000m), the conveyance efficiency has been reported as 60, 70 and 80% for sand, loam and clay soil respectively. On the other hand for medium length unlined canals (200-2000m), Ec is 70, 75 and 85% for sand, loam and clay soil respectively; while for short canals (<200m) the magnitude is nearly 80, 85 and 90% for sand, loam and clay soil respectively. The efficiency of lined canals has been reported in the order of 95% for all canal length.

2.5.7. Application efficiency

The field application efficiency mainly depends on the irrigation method and the level of farmer discipline. Some indicative value of the average field application efficiency are 50-60%, 60-80% and more than 80% for surface, sprinkler and drip irrigation methods respectively (FAO, 1989). However according to Roger *et al.,* (1997), it is possible to have high application efficiency and 50-90% can be used for general system type comparison. Walker (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%. Lasley (2002), suggested that it could be in the range of 50-80%. In general, according to Micheal (1997), water application efficiency decrease as the amount of water applied during each irrigations increase.

2.5.8. Water storage efficiency

Storage efficiency is an index used to measure irrigation adequacy. It is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root zone. The value of storage efficiency is important either when 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. This parameter is the most directly related to the crop yield since it will reflect the degree of soil moisture stress (Eticha S, 2011).

The water storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application. Zerihun *et al.,* (1997), also defined storage efficiency as a ratio of the volume of water actually stored in the subject region to the volume of water that can be stored.

Small irrigations may lead to high application efficiency, yet the irrigation practice may be poor. The concept of water storage efficiency is useful in evaluating this problem

2.5.9. Distribution uniformity

Distribution uniformity (Du) is a measure of how uniformly water is applied during an irrigation event. The uniformity of application can have a considerable effect on crop yield and optimum water application. There are several interpretations of in the literature, but a common measure for surface irrigation systems is to divide the average depth infiltrated from the quarter of the field with the lowest infiltrated depth, by the average infiltrated depth. This is called the 'lower quarter'.

When a field with a uniform slope, soil and crop density receives steady flow at its upper end, a waterfront will advance at a monotonically decreasing rate until it reaches the end of the field (FAO, 1989). Roger et al. (1997) explained that water lost to percolation below the root zone due to non-uniform application or over-application water runoff from the field all reduces irrigation efficiencies.

2.6. Maintenance indicators

Maintenance of irrigation systems intends to accomplish the following main purposes:
The first purpose is to 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.

The second purpose is to keep water control infrastructure in working condition (Boss *et al.*, 2005). The performance of the scheme could also evaluated through maintenance performance indicators; Maintenance indicators give practical information on the sustainability of the intended water level. The maintenance indicators are; water surface elevation ratio, effectiveness of infrastructures and sustainability of irrigated as recommended by (Bos, 1997).

Maintenance performance inspection of the scheme would provide to insight the feature of the conservation of the system. Bos *et al.*, (1997), state that the maintenance innovations of 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.

2.6.1. Water surface elevation ratio

This indicator provides to foresee the impact of sedimentation and erosion problems on the physical irrigation system. If there is a rise or drop of the water surface elevation, which indicates that maintenance are being required (Shafique, 1993). It was computed by taking the actual water depth from the canal bottom and comparing it with the design water depth at the same position in the main canal. The parameter is defined by measuring the actual water surface elevation at the intended water level recorded below the full supply level. If a value is greater than one it would expected to indicate an erosion problem or overcapacity of a canal resulting from inaccurate dreading or cleaning activity. While, if the value of water surface elevation ratio is less than one, then there is a probability of rising canal bead level due to siltation and weed incidence in a canal (Boss *et al.*, 1993).

2.6.2. 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 indicate the need for maintenance or rehabilitation of the physical structures (Boss *et al.*, 2005; Kloezen and Garces, 1998).

2.6.3. 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 is not attended to properly, may shorten the system's life.

The intensity with which the irrigated area is cropped traditionally is a function of the number of crops per year grown in 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 (water logging, 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 water logging or salinity. Irrigated area sustainability refers to the percentage of change in irrigated area over the period of years (Gorantiwat and Smout, 2005). Sustainability of irrigated area is measured as the ratio of existing area under irrigation to the planned irrigated area (Bos, 1997).

2.7. Organizational indicators

The main organizational indicator in an irrigation scheme is water user association. They are formed from the members of water user as its name indicates. Nowadays, attention is being focused on how to achieve this commitment, and to what extent water user association can be assisted to form and to manage their own affairs (FAO, 1996). Many conflicts occur due to the problem of water theft or unauthorized canal breaching in the scheme. There is a conflict resolution mechanism and most water user association develop their by-laws which is a system rules for controlling the conflict within the scheme. The water user association committees have long existed to manage small-scale irrigation scheme. They are generally well organized and effectively operated by farmers. The associations handle construction, allocation, operation and maintenance functions with government technical and material support (MoWR, 2002).

Top-down approach and operational autonomy in irrigation systems was the causes for the failure of irrigation scheme which constructed after constructed 1975.Operation, management and maintenance activities by the centralized governmental were also usually inadequately performed (MoWR, 2002). Since 1991, farmers or communities are forming their own organizational structures. Currently, known as water user association for own and autonomous management of irrigation schemes with support from government and non-governmental organizations (FAO, 1998; MoWR, 2002).

2.8. Determining sample size

Perhaps the most frequently asked question concerning sampling is “What sample size do I need”. The answer to question is influenced by a number of factors, including the purpose of the study, population size, the risk of selecting “bad” sample, and the allowable sampling error.

2.8.1. Sample size criteria

In addition to the purpose of the study and population size, three criteria usually will need to be specified to determine the appropriate sample size: the level of precision, the confidence or risk and the degree of variability in the attributes being measured (Miaoulis and Michener, 1976).Each of these is discussed below.

A) Level of precision

The level of precision, sometimes called sampling error, is the range in which the true value of the population is estimated to be. This range is often expressed in percentage points, (e.g. ±5Thus, if a researcher found that 60% of farmers in the sample have adopted a recommended practice with a precision rate of ±5% he or she can concluded that, 55% to 65% of farmers in the population have adopted the practice.

B) Confidence level

The confidence or risk level is based on ideas encompassed under the central limit theorem. The key idea encompassed in the central limit theorem is that when a population is repeatedly sampled, the average value of the attribute obtained by those samples is equal to the true population value. Furthermore, the values obtained by these samples are distributed normally about the true value, with some samples having a higher value and some obtaining a lower score than the true population value. In normal a distribution .approximately 95% of the sample values are within two standard deviations of the true population.

In other words, this means that, if a 95% confidence level is selected, 95 out 100 samples will have the true population value with in the ranges of precision specified earlier. There is always a chance that the sample you obtain does not represent the true population value.

C) Degree of variability

The third criterion, the degree of variability in the attributes being measured refers to the distribution of attributes in the population. The more heterogeneous a population, the larger the sample size required to obtain a given level of precision. The less variable (more homogeneous) a population, the smaller the sample size. Note that a proportion of 50% indicates a greater level of variability than either 20% or 80%. This is because 20% and 80% indicate that a large majority do not or do, respectively, have the attribute of interest. Because a proportion of 0.5 indicates the maximum variability in a population, it is often used in determining a more conservative sample size, that is, the sample size may be larger than if the true variability of the population attribute were used.

2.8.2. Strategies for determining sample size

There are several approaches to determining the sample size. These include using a census for small populations, imitating a sample size of similar studies, using published tables, and applying formulae to calculate a sample size. Each strategy is discussed below.

A) Census for small population

One approach is to use the entire population as the sample. Although cost considerations make this impossible for large populations, a census is attractive for small populations (e.g., 200 or less). A census eliminates sampling error and provides data on all the individuals in the population. In addition, some costs such as questionnaire design and developing the sampling frame are "fixed," that is, they will be the same for samples of 50 or 200. Finally, virtually the entire population would have to be sampled in small populations to achieve a desirable level of precision.

B) Sample size of a similar study

Another approach is to use the same sample size as those of studies similar to the one you plan. Without reviewing the procedures employed in these studies you may run the risk of repeating errors that were made in determining the sample size for another study. However, a review of the literature in your discipline can provide guidance about "typical" sample sizes which are used.

C) Published tables

A third way to determine sample size is to rely on published tables which provide the sample size for a given set of criteria. It present sample sizes that would be necessary for given combinations of precision, confidence levels, and variability.

D) Formulae to calculate a sample size

Although tables can provide a useful guide for determining the sample size, one may need to calculate the necessary sample size for a different combination of levels of precision, confidence, and variability. The fourth approach to determine sample size is the application of one of several formulae developed by Yamane is selected for this study because it is simplified and easy to estimate the number of samples for any number of population and also has a relationship with published table values of samples.

3. MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location

Golina small-scale irrigation project is located North Wollo Zone, Kobo wereda, and Abuare kebele. It is one of the sub-basins of Danakil basin located in northern part of eastern Amhara development corridor. The command area is bounded by Hormat and Golina rivers in the northeast and south. In the west a gravel road from Kobo town to Abuarie Keble delineates and divides the command area as the main accesses road having 13km of distance. The project area is located about 170km from Dessie Town and 570km North of Addis Ababa. The geographical location of the project site is varying from 572542 to 577111.18 easting using UTM and varying from 1334652 to 1334124.89 northing using UTM. Altitude- varying from 1363.70 to 1414.68 m.a.s.l.

Golina small-scale irrigation project is a river diversion irrigation project studied and designed by Amhara design and supervision works enterprise (ADSWE). The development of the irrigation scheme began in the dry season of 2011.

The project command area encompasses 185ha downstream of Abuare village on the left side of Golina River. The diversion weir is located downstream of Golina bridge (bridge constructed on the Addis–Mekelle road). The length of the main canal is 1149m lined and 935m unlined section. Te total length of the main canal is 2084m.The main canal operates continuously for 12hours, providing water during the day to the 2374m secondary canal-1 and 2280m secondary-2, each irrigating 95 and 90ha respectively. The irrigation system also has a network of field irrigation canals, culverts and service roads. Other structures like division boxes with gates and turnouts were constructed and currently some of the structures are non-functional.

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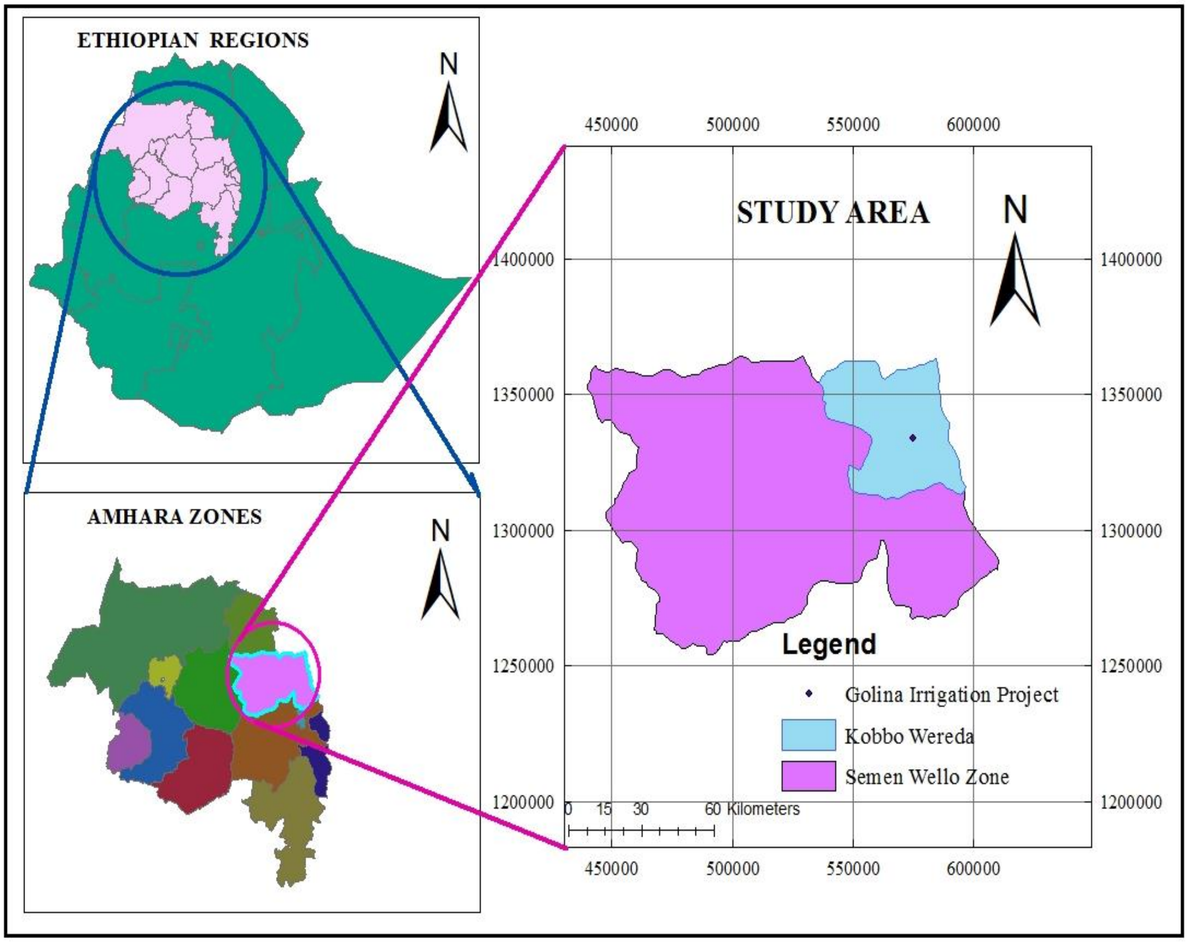


Figure 3. 1: Location map of the study area

Figure 3. 2: Golina irrigation headwork structure

Figure 3. 3: Functional division box with gates

3.1.2. Climate

The area receives 683mm average rainfall annually. About 20% of the rainfall is received in the months of February to March, considered the minor rainy season, and the remaining rain is received during the months of July and August, the main rainy season. Late onset, early secession and uneven distribution of the rains shorten the effective rainy season and results in late dry spells. Therefore, rain fed cropping is often unreliable, and there is recurrent drought. It is found in the kola agro-ecological zone. The mean annual maximum and minimum temperature are 32.9 and 11.7^{o}C, respectively.

3.1.3. Soil type

The dominant soil type of the command area is clay soil. Seasonal soil cracking and swelling are observed in the scheme. It was checked by laboratory analysis at Sirinka Agricultural Research Center (From soil textural analysis result).

3.1.4. Crop type

The major crops grown in Golina small-scale irrigation scheme are maize, teff, cabbage, sorghum, tomato, onion and pepper. Teff and maize are grown as rain fed and irrigated crops while sorghum particularly those long maturing types are exclusively grown under rain fed condition.

3.2. Materials

Materials used to conduct this study are listed in the table below (Table 3.1).

Table 3. 1: Materials used for sample collection and analysis

Number	Material type	Purpose
1	Core sampler	To collect undisturbed soil samples for soil moisture test
2	Auger	To dig soil samples for texture analysis
3	Oven dry	To dry the wet soil
4	Measuring tape (50 m)	To Measure the dimension layout of the farm
5	Stopwatch or clock	To record time
6	Analytic balance	To measure soil weight
7	Parshall flume	To measure the rate of flowing water in the field canal
8	Plastic Bag	To take soil samples to the laboratory
9	GPS	To collect different coordinate points
10	Water level	To check the slope of Parshall flume
11	Hammer	To hit the core sampler
12	Stakes	To fix the measuring place
13	Floating object	One liter empty bottle(Flow velocity measurement)
14	Staff gauge	To insert it to measure water depth

3.3. Methods

3.3.1. Data sources and methods of data collection

The required data were collected from both primary and secondary sources. The primary data were collected from field by direct measurement such as; discharge, water surface elevation, soil samples(laboratory), field plot dimensions, questionnaires and field observation of irrigation infrastructures. Whereas, secondary data from different offices and design documents.

3.3.1.1 Primary data

The primary data were collected directly from the field and laboratory. Such activity includes; discharge measurements, measurement of actual water surface elevation in the main canal, questionnaires, number of beneficiary farmers/households from Abuare kebele, filed observations and laboratory results. The details of the way, locations (sites) and time of collecting these data are discussed in the following section.

A) Flow measurement

Flow measurement is one of the main activities of data collection. It helps to know the conveyance and application efficiency. Flow measurement takes place both conveyance and water application area. The field application water is measured by Parshall flume which is a horizontally constricted vertical throat in an open channel used to measure the discharge entering into the field (sample) plot.

The canal discharge were measured by area-velocity method due to the absence of other materials (current meter) in the Sirinka Agricultural Research Center and technological limitation to use discharge app software (not licensed) to use it. So, the only option is to use area-velocity method. Difficult to use Parshall flume because canal is too large.

I) estimation procedure

The following presents the procedure for measuring the discharge using a floating object.

Equipment:

- ✓ Measuring tape at least 5m long
- ✓ 4 Stakes
- ✓ Stopwatch or watch capable of measuring time in seconds
- ✓ Floating object such as a bottle or coconut

Procedure:

Step 1: Select a straight section of the canal at least 10m long. The shape of the canal along this section should be as uniform as possible

Step 2: Place two stakes, one each side, at the upstream end of the selected portion of the canal. They should be perpendicular to the centerline of the canal

Step 3: Measure 10 meters or more along the canal

Step 4: Place two stakes at the downstream end of the selected section of the canal, also perpendicular to the centerline of the canal

Step 5: Place the floating object on the center line of the canal at least 5m upstream of point and start the stopwatch when the object reaches point where first stakes are placed

Step 6: Stop the stopwatch when the floating object reaches point of downstream stakes location, and record the time in seconds

Step 7: Repeat steps 5 and 6 at least four times in order to determine the average time necessary for the object to travel from one point to another point. The object should not touch the canal embankment during the trial, but if it does the operation must be repeated and the time for the bad trial must not be included when calculating the average time

Step 8: Measure the canal cross section at the selected canal section.

Step 9: Calculate the surface velocity, Vs, and then the average flow velocity, V, using the equations Vs = L / t, where t is the travel time is seconds, based on the average of four clear runs of the floating object, and $V=0.75*V_s$ 0.75 is a constant velocity reduction factor. This is used by FAO (1985 to 1993), as a reduction for turbulent nature of the flow to have a mean velocity. The relationship with the depth of flow is another reason. So, my canal depth was in the range of the corresponding correction factor

Step 10: Calculate the wetted area of the cross-section

Step 11: Calculate the discharge, Q, in the canal, Q = V * A Where Q in m^3/s

B) Field observation

For the period of field observation, the conditions of existing irrigation structures were inspected during off and on irrigation time. During field observation the overall operational activities were identified and a number of functional and non-functional structures in the scheme were recorded.

The purpose of field observation were to know the number of operational and non-operational structures for effectiveness analysis and to identify damaged irrigation structures for conducting or suggesting maintenance activities.

C) Water surface elevation measurement

Measurement of water surface elevation of the main canal during irrigation season were considered at the head, middle and tail reach of the system is important to identify scouring and siltation locations on the conveyance system. At each reach of the main canal, the actual data were taken at every ten meter distance intervals along the main canal up to the entire length (representative monitoring locations). The actual water surface depth from canal bottom were measured by using staff gauge and measuring tape meter.

D) Soil sample collection

To determine soil texture of each farmer's field plot, nine (9) composite soil samples from three locations from each scheme at three different depths were collected. And also using core sampler undisturbed soil samples were collected from different depths and the bulk densities at different depths were determined. Soil samples were also collected to determine the soil moisture content two day before and after irrigation event by collecting soil samples from the scheme with an interval of 30cm to a depth of 90cm. It is based on the major crops depth that planted on the scheme that the effective root zone of the irrigated vegetable crop is not more than this depth. Here, the major crops that are grown in the area have a depth less equal or the depth taken for the study. The maximum effective root zone of onion and tomatoes is 90cm (Allen *et al.,* 1998).The moisture content of the collected soil samples was determined using gravimetric method.

The soil samples were taken on the selected field plots with different depth intervals down the pit using different materials. The collected samples were used to determine bulk density, soil texture, soil moisture content, field capacity, permanent wilting point and others. The sample field plots were selected based on the availability of water reaching from the conveyance system or distance from the water source to the command area.

E) Sampling methods

In this study a random sampling method was used to select the farmers for the surveys. To evaluate farmer's perception about scheme performance and institutional aspects a sample were taken from the beneficiaries of the irrigation schemes by preparing questionnaires.

3.3.1.2. Secondary data

Secondary data included necessary reports, project documents, studies and other useful written materials were collected from different sources. These data included design and layout of the scheme, design of conveyance and water control structures, irrigated area, area irrigated per crop per season/year, crop types and number of farmers, were obtained from North Wollo Agricultural and Natural Resource Department.

A) Climatic and meteorological data

The area receives 683mm average rainfall annually. About 20% of the rainfall is received in the months of February to March, considered the minor rainy season, and the remaining rain is received during the months of July and August, the main rainy season. Late onset, early secession and uneven distribution of the rains shorten the effective rainy season and results in late dry spells. Therefore, rain fed cropping is often unreliable, and there is recurrent drought. It is found in the kola agro-ecological zone. The mean annual maximum and minimum temperature are 32.9 and 11.7^{o}C, respectively.

As per the meteorological data, the area receives 683mm average rainfall annually, about 20% of the rainfall have received in the months of February to May, considered the minor rainy season, and the remaining rain is received during the months of July and August, the main rainy season. Uneven distributions of the rains shorten the effective rainy season and results in late dry spells. Therefore, rain fed cropping is often unreliable, and there is recurrent drought. The study area is found in the kola agro-ecological zone. The mean annual maximum and minimum temperature are 32.9 and 11.7^{o}C, respectively.

3.4. Data analysis method

3.4.1. Scheme performance evaluation

The sample plots were selected from three farmers' field/Three sample field plots for simplicity of analysis. It means that, the soil samples from three reaches (Head, middle and tail).Three sample plots were selected at each reach. Each of the fields were located at the head, middle and tail-end, to compare their irrigation water use efficiencies of the irrigation scheme. The performance evaluation was based on the four performance indices. These are field application efficiency, conveyance efficiency, water storage efficiency and distribution efficiency of the irrigation scheme.

3.4.1.1. Application efficiency

Application efficiency is very important term in irrigation practice to determine the performance of the scheme. Based on the application efficiency result the scheme can categorized as good or bad and remedial measures will or will not be taken. The application efficiency can be determined after determining the depth of water actually applied into the fields using a Parshall flume 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 and located in the head, middle and tail-end of the water source. To measure this indicator, moisture content of the soil and amount of irrigation water supplies were required in each sample plots.

A) Measurements of moisture content of the soil

Soil moisture content measurement is necessary to know the moisture holding capacity of the soil of the command area for different parametric analysis which have relationship with soil. For example application efficiency, water storage efficiency field capacity and permanent wilting point and rooting depth determination. Thirty six (36) number of soil samples were collected to determine moisture content of soil from three plots/sample field plots at the three reaches of irrigated area (after irrigation) and thirty six before irrigation which is totally seventy two (72) soil samples. The samples were taken at field's depth an interval of 30cm to maximum of 90cm depth.

The figure thirty six indicates that, for one growth period, 9 average soil samples were taken at each pit or 9 samples before irrigation and 9 samples after irrigation which is 18 soil samples for one irrigation season with depth interval of 30cm.Then for four growth stages (Initial, development, middle and late) equals to 72 soil samples (18x4=72). It is assumed that this depth (90cm) is the effective root depth of the irrigated vegetable crops. The maximum effective root zone of small vegetables, like onion and tomato is 90cm (Allen *et al.*, 1998). Samples were taken before and two days after irrigation events. Two day is selected after irrigation to take soil sample is because of gravitational water will lost after two days and irrigation water will remain after two days. This is based on the soil texture of the field. This depth was considered as effective root zone of the crop at the time of measurement. The soil samples were placed in containers of known weight and then weighed. The samples were dried in an oven for 24hours at temperature of 105°C with the containers cover removed. After drying, the soil and container were again weighed and the weight of water determined as following pre and post readings.

Soil moisture content in each sample on weight basis in fraction (θ_w) was calculated using the equation (FAO, 1989):

$$\theta_w = \frac{Ww-Wd}{Wd}x100$$ ---Equation 3. 1

Where: θ_w= Soil water content on a dry weight basis,

W_w= Wet weight of the soil gm,

W_d= Dry weight of the soil gm

B) Determination of Soil texture, Bulk density, Field capacity and Wilting point

Soil samples were taken to analyze the soil texture, bulk density, field capacity and wilting point. The sampling points for the analysis of each parameter were distributed systematically over the scheme so that most parts of the fields are represented.

i) Soil texture and Bulk density

To determine soil texture, 9 composite samples of disturbed soil were collected from different locations in the field and for the determination of soil textural class soil samples at the specified depths were taken at each stratum (head, middle and tail). Soil particle size composition of each particle was calculated in laboratory. Based on the percentage of composition, the soil textural class was determined by USDA soil textural triangle method (Bouyoucos, 1951).

Bulk density was determined using 9 undisturbed soil samples collected from three pits with core samplers volume of 98.4cm^3 at interval of 30cm each. The samples were placed in an oven and dried at 105°C for 24 hours. After drying, the soil and container were again weighed. The dry weight of the soil was divided by the sample volume to determine the dry bulk density. The dry bulk density (ρ_b) was computed by dividing the oven dry mass of the soil sample (m_d) to known volume of core sampler (V_b) (Blake, 1965) as:

$$\rho_b = \frac{md}{Vb} \quad \text{Equation 3. 2}$$

ii) Field capacity, Wilting point and Soil water availability

Moisture contents at field capacity and wilting point were determined using disturbed soil samples collected from three sampling points at interval of 30cm. For the determination of total available water (TAW) amount in the soil; Field capacity (FC) and Permanent wilting point (PWP) of the soil was determined by taking soil samples. This was done using Gravimetric method (Easily available, cheap and fairly accurate values) in the laboratory. Soil moisture content was observed for the determination of field capacity and permanent wilting point, respectively at the Sirinka soil laboratory center. Clear description of how moisture content determine from permanent wilting point.

Materials:

- ✓ Auger
- ✓ Soil moisture boxes
- ✓ Oven
- ✓ Analytic Balance

Procedure:

- ✓ Take the soil samples from the field where plant leaves show sign of wilting
- ✓ Take soil samples with soil auger from pre-determined depths below ground surface and put them in moisture boxes
- ✓ Weigh the moisture box alone (W_1), gm
- ✓ Weigh each soil sample (about 100 gm) along with moisture box (W_2), gm
- ✓ Place soil samples with box in the oven for 24 hours at 105^0c
- ✓ Weigh the dry soil sample with box (W_3), gm
- ✓ Estimate soil moisture content on percent weight basis

$$MCw = \frac{((W2-W1)-(W3-W1))}{W3-W1} * 100$$

- ✓ Determine soil moisture content on volume basis (MCv) = MCwxBD, BD= bulk density

Total available water (TAW) which is an estimate of the amount of water a crop can use from the soil for the selected fields were computed from the moisture content in volume percent at field capacity and permanent wilting point as (FAO,1989).

TAW = 1000 x (θ_{FC} - θ_{wp}) x Ds -- Equation 3. 3

Where:

TAW = Total Available Water in the root zone mm,

θ_{FC} = water content at field capacity m^3/m^3,

θ_{WP} = water content at wilting point m^3/m^3, Ds = Rooting depth m

After drying, the soil and container were again weighed and the weight of water determined as pre and post readings. The depth (Ds, m) of water retained in the soil profile in the root zone was determined using the following equation given by Misra and Ahmed (1990).

$$Ds = \sum_{i=1}^{n} \left(\frac{\theta AI - \theta BI}{100}\right) ixDi$$ -- Equation 3. 4

Where θ_{AI} and θ_{BI} are moisture content of the i^{th} soil layer after and before irrigation on oven dry volume basis (%), respectively;

D_i is thickness of i^{th} soil layer (m) and n is number of layer in the root zone

C) Amount of water applied to the fields

To determine the amount of water applied by the farmers to the selected fields, a Parshall flume was installed at the entrance of each field of interest /plot/ to measure the depth of water applied to the field. During the determination of the amount of water applied to the field, the average water depth of irrigation water passing through the flume to the field and respective time was recorded with the size of the fields being irrigated.

To determining the depth of water actually applied into the fields and the depth of the water retained in the root zone of the soil, moisture contents of the soil is required before and two days after irrigation. To measure this indicator, moisture content of the soil and amount of irrigation water applied were required in each sample plots for three growth stages of the crop. In this research soil samples were collected from the fields at different depths (0-30, 30-60 and 60-90 cm) and the amount of water stored in the root zone was determined. The application efficiencies (Ea) in the selected fields were calculated using equation below (Hansen *et al.,* 1980).

$$Ea = \frac{Ds}{Da} x100 \qquad \text{Equation 3. 5}$$

Where Ea= water application efficiency %

Ds = water stored in the soil root zone during the irrigation mm

Da = water delivered to the farm mm

3.4.1.2. Conveyance efficiency

For the determination of conveyance efficiency in the main canal, as it is too large for the flume, area-velocity method was used. The discharge rate in the canal was determined using velocity area method. Floater was used and the time taken to travel 10m canal length was recorded using stopwatch. Velocity was calculated as distance to average time ratio and the discharge rate was obtained by multiplying average cross-sectional area by the velocity. After determining the amount of water supplied by the conveyance system and total inflow into the conveyance system, the conveyance efficiency was calculated using the following equation. Conveyance losses refer to the fraction that is lost when irrigation water travels from its source to the field through the conveyance network, including losses due to seepage, leakage and overtopping.

Conveyance efficiency = $\frac{Total\ water\ supply\ by\ the\ conveyance\ system}{Total\ inflow\ into\ the\ conveyance\ system}$--------------------- Equation 3. 6

3.4.1.3 Storage efficiency

The water storage efficiency refers to how completely the water needed prior to the irrigation root zone during irrigation. It is the ratio of water stored in the root zone during irrigation to the quantity of water needed in the root zone before irrigation. Based on the FC, PWP and bulk density of the soils of the selected irrigation fields and the root depth of the crop irrigated, the depth of irrigation water required by the crop was calculated as actual soil moisture depletion level (Allen *et al.*, 1998). After determining the water stored in the root zone of the plants and water needed in the root zone prior to irrigation, the storage efficiency (Es) was computed as:

Storage efficiency = $\frac{Ds}{Dreq}$x100-- Equation 3. 7

Where;

Ds is depth of water retained in the soil compartments of the root zone (mm) which is computed by equation 3.4 and Dreq is water depth required in the root zone(mm) prior to irrigation and was estimate by the following equation:

Dreq = $\sum_{i=1}^{n} \frac{\theta Fc - \theta BI}{100} ixDi$-- Equation 3. 8

Where;

θ_{BI} = ith layer of volumetric moisture content before irrigation (fraction)

θ_{FC} = ith layer of volumetric moisture content at field capacity (fraction)

D_i = ith layer of crop root depth (mm) n = number of layers in the root zone

3.4.1.4. Distribution Uniformity

To determine the distribution uniformity of irrigation water in the selected farmer's field augur samples were taken from the selected points. Soil samples were collected from different depths with an interval of 30cm up to 90cm. Then the soil moisture contents of the soils at the selected points were analyzed to determine the depth of water distribution. Distribution uniformity was defined as the minimum infiltrated depth divided by the average infiltrated depth (Jurriens et al, (2001).

$DU = \frac{Minimum\ depth\ (cm)}{Average\ depth(cm)} * 100$--*Equation 3. 2*

3.4.2. Maintenance indicators

Maintenance performance inspection of irrigation scheme would provide to insight the feature of the conservation of the system. Bos *et al*., (1993), state 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. Maintenance requirements of the system were assessed according to maintenance indicators of water surface elevation ratio, effectiveness of infrastructure, and sustainability of irrigable area under the category of physical structures in its operational condition such as an operative, nearly operative, nearly inoperative and inoperative. The physical structures in the system becoming non-operational due to broken of structure, change of canal cross-section, scouring of canal section, missing of flow control and distribution facilities, damaging of the structure, sedimentation and weed growth (Samad and Vermillion, 1998; Vermillion *et al.,* 1999). Maintenance inspection of the performance of irrigation scheme would provide to insight the features of maintenance situations. Proper maintenance enables the keeping of water level control and distribution infrastructure in good working condition.

Proper maintenance enables the keeping of water control infrastructure in good working condition so that the design water level is maintained. The head loss across structures (water level difference between upstream and downstream of structure) in irrigation canals is the most important factor disrupting the intended delivery of irrigation water. The maintenance indicators were evaluated by the following performance indicators (Boss, 1997).

3.4.2.1. Water surface elevation ratio

The term water surface elevation ratio indicator provides to predict the impact of sedimentation and erosion problems on the main canal of the scheme. The water surface elevation ratio inspection was made at the head, middle and tail reach of the main canal. The water surface elevation ratio was examined with the standard recommended by (Bos *et al.* 1993); (Bos 1997); (Kloezen and Garces 1998); and (Bos *et al.*, 2005).

When the value of water surface elevation ratio is equal to or close to 1.00, this implies that the main canal is keeping of water conveyance and distribution system in good working condition. Hence, the main canal is free of sediment accumulation and erosion. Therefore, conveyance structure supply water as its intended capacity. However, the WSER value greater and less than one indicates that the main canal is affected by the problem of erosion and sedimentation respectively (Bos *et al*., 1993; Mamuye and Mekonen, 2015).Water surface elevation ratio (WSER) can be calculated as:

$$WSER = \frac{AWSE}{IWSE} \quad \text{Equation 3. 10}$$

Where, AWSE is actual water surface elevation at full supple level;

IWSE is intended or designed water surface elevation at full supple level;

3.4.2.2. Effectiveness of infrastructure

The assessment of the effectiveness of infrastructure was focused on the physical structures in irrigation system components. Effectiveness of infrastructure is the ratio of functional to total number of structures initially installed. Under this parameter, the level of maintenance requirement of the system was assessed in two sub sections; the first one was by computing the ratio of actually functional structures and total number of structures initially installed. The second one was based on the ratio of actual functional (operated) length to total length of main and secondary canals. For my study case the second one was used.

The computed values of the ratio (percentage), performance were classified according to Mamuye and Mekonen, (2015) as “operative”, “nearly operative” and “inoperative”. As the deviation of effectiveness of infrastructure ratio more than 5% would signal the need for repair or rehabilitation of the physical structures (Boss *et al.*, 2005; Kloezen and Garces, 1998).To determine the affectivity of the infrastructure of the irrigation system, all the infrastructures including diversion weir, head regulator, the drop structures, the division boxes and main canals off take gates (gates closure) which were positioned on the main and secondary canals were monitored during the field observations.

$$\text{Effectiveness of infrastructure (EI)} = \frac{Number\ of\ functioning\ structures}{Total\ number\ of\ structures\ initially\ installed} \quad \text{Equation 3. 11}$$

3.4.2.3. Sustainability of irrigated area

Sustainability of irrigated area (SI) is measured as the ratio of existing area under irrigation in the planned irrigated area (Bos, 1997). This indicator enabled to investigate the variation in the area actual irrigated against the planned area in terms of ratio and provide valid reasons for such variation (Raghava, 2011). Thus, the actually irrigated area was estimated using GPS, whereas planned command area was obtained from design document. Then, SI was computed using equation 3.12. When the value of SI is equal and/or close to 1.00, this implies that the irrigated area is keeping its design state, similarly, SI value greater than one indicates that the expansion of irrigated (command) area. When SI greater than one, improvement in the conveyance and distribution is essential in order to feed sufficiently the initially plane and extra expanded command area. However, the SI value less than one indicate the irrigated area is reduced compared to the intended; hence rehabilitation or repair requirement of the system is required (Bos *et al*., 1993; Raghava, 2011).

$$Fs = \frac{Fc}{Fi}\, x100 \qquad \text{Equation 3. 12}$$

Where F_c is the current irrigable area in ha; F_i is the initial irrigable area in ha (*Bos et al.*, 1994).

3.4.3. Sampling methods

In this study a random sampling method was used to select the farmers for the surveys. In order to evaluate the farmers' perception about scheme performance and institutional aspects a sample size of 91 farmers were chosen out of 970 farmers which own irrigable land for head, middle and tail-end. Yamane (1967), provides a simplified formula to calculate sample sizes.

$$n = \frac{N}{1+N(e)^2} \qquad \text{Equation 3. 13}$$

Where; n is the sample size;

N is the population size; e is designed level of precision

e =10% precision level

$$n = \frac{970}{1+970(0.1)^2} = 91$$

3.4.5. Institutional and support service evaluation

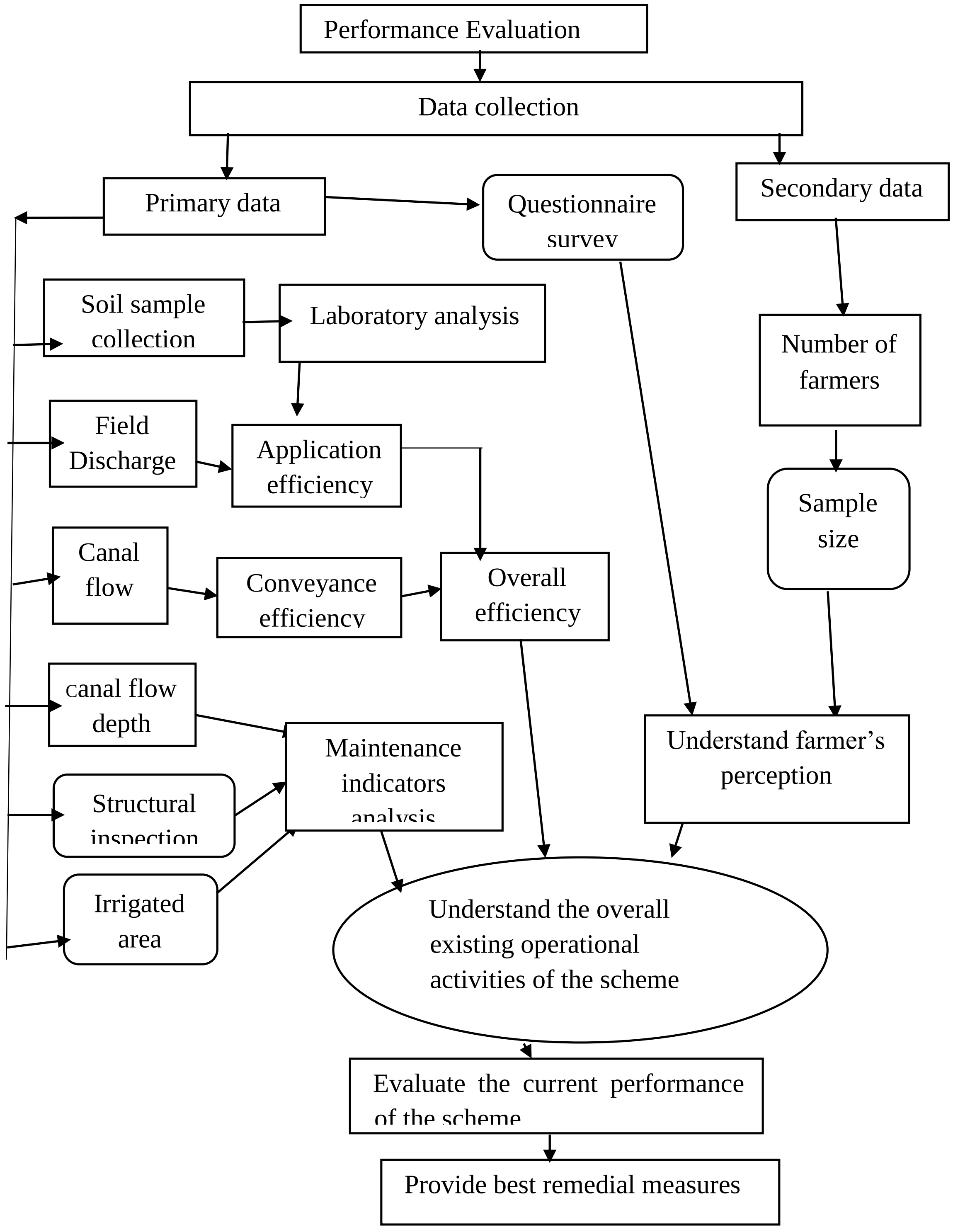
To evaluate the farmers perception with regard to scheme performance and institutional aspects a sample size of 91 farmers were chosen from 970 farmers which own irrigable land. Stratification of the scheme were based on location relative to the canals as head, middle and tail end users. Key constraints of scheme performance including water management, sustainability and maintenance activity of the scheme, conflict and conflict resolution mechanisms and support services were conducted through interview.

3.5. Over all irrigation efficiency

The most common way to express the efficiency of irrigation systems is to subdivide it in to conveyance and application efficiencies. Once the conveyance and application efficiencies have been determined, the scheme irrigation efficiency (Eo) can be calculated, using the following formula (FAO, 1989).

$Eo = \frac{Ec\ x Ea}{100}$-- Equation 3. 9

3.6. Conceptual framework



4. RESULT AND DISCUSSION

4.1. Soil data result analysis

Soil samples were taken at depth interval of (0-30, 30-60 and 60-90cm) to investigate the physical properties of the irrigation scheme at different location. From the sampled soil texture, bulk density, field capacity (FC), and permanent wilting point (PWP) were analyzed.

4.1.1. Soil texture and bulk density

According to the USDA textural classification, the soil texture of the project (study) area was exclusively clay (Table 4.1). As seen in Table 4.1 the bulk density varied from high as 1.08g/cm^3 to the minimum of 1.01g/cm^3. Miller and Donahue (1995), recommended soil bulk density below 1.4gm/cm^3 for clays and 1.6gm/cm^3 for sands in order to get better plant growth. The current result is in agreement with the classification suggested by (Miller and Donahue, 1995). Hence, the soil of the study area found to be suitable for plant growth. The bulk density values ranges from 1.01 to 1.08 g/cm^3 scheme. The bulk density values of the soils at the irrigation scheme were low as per the bulk density rating of Jones *et al.,(*2003), indicating that there was no compaction that could limit infiltration of water into and through the soil and root penetration.

Table 4.1: Soil properties of the selected fields

Soil depth(cm)	% Sand	% Silt	% Clay	Textural class	Bulk Density(g/cm^3)	Sample plot
0-30	17.79	28.77	53.44	Clay	1.08	Head reach
30-60	23.75	24.72	51.53	Clay	1.04	
60-90	19.13	25.39	55.48	Clay	1.01	
0-30	14.65	29.86	55.49	Clay	1.07	Middle-reach
30-60	17.41	26.01	56.58	Clay	1.06	
60-90	22.26	24.85	52.89	Clay	1.02	
0-30	16.14	27.89	55.97	Clay	1.08	Tail-reach
30-60	19.13	23.99	56.88	Clay	1.04	
60-90	23.99	22.92	53.09	Clay	1.02	

4.1.2. Soil moisture content at field capacity and permanent wilting point

The soil moisture content at field capacity varied from 0.303m^3/m^3 to 0.40m^3/m^3 by volume, while the soil moisture at permanent wilting point varied from a minimum value of 0.210m^3/m^3 to the maximum value of 0.237m^3/m^3 on volume basis (Table 4.2). The total available soil moisture varies from the lower value of 92mm/m to higher value of 176mm/m. The value of FC, PWP and TAW were found to be in the range given by FAO (1998) Appendix table 7.1.TAW varies from (0.12-0.20) m^3/m^3 on volume basis according to FAO (1998).

Table 4.2: Average soil moisture for three growing seasons (FC, PWP, and TAW) and bulk density

Plot	Soil depth cm	$\theta_{fc}(m^3/m^3)$	θ_{wp} (m^3/m^3)	Bulk density	TAW(mm/m)	TAW(mm)
Head	0-30	0.400	0.237	1.08	176	158.4
	30-60	0.379	0.234	1.04	144	129.6
	60-90	0.373	0.231	1.01	141	126.9
Middle	0-30	0.377	0.234	1.07	142	127.8
	30-60	0.368	0.233	1.06	134	120.6
	60-90	0.356	0.232	1.02	123	110.7
Tail	0-30	0.318	0.234	1.08	83	74.7
	30-60	0.316	0.226	1.04	89	80.1
	60-90	0.303	0.21	1.02	92	82.8

4.2. Performance indicators evaluation of the scheme

The parameters assessed for performance evaluation of Golina small-scale irrigation scheme were include the following. Conveyance efficiency, water storage efficiency, maintenance indicators and application efficiency are the parameters. Institutional and support service evaluation was also conducted to incorporate local knowledge and perspective on the irrigation system.

4.2.1. Conveyance efficiency

The conveyance efficiency, Ec measures the percentage of discharge entering the system that is recorded as having been allocated to the water management units.

Conveyance efficiency of the systems was computed using equation (3.6) considering the total flow delivered by conveyance system and total inflow into the system (Table 4.3). During the study period, average conveyance efficiency of the main canal from main intake up to the tail end considering different measuring locations of discharge using area-velocity method.

Table 4.3: Average canal conveyance efficiency

System	Mean discharge inflow(m^3/s)	Mean discharge outflow (m^3/s)	Ec (%)
MC-1 (0-1149m) Lined rectangular	0.45	0.38	84.44
MC-2unlined (1149-2084m) trapezoidal	0.38	0.30	78.95
Division box to SC-1 (0-2374m)	0.17	0.11	64.71
Division box to SC-2 (0-2280m)	0.13	0.09	69.23

Table 4.3 above shows that the conveyance efficiency of the concrete lined (0-1149m) main canal was 84.44%. The amount of water lost in 1149m length of main canal was 0.07 m^3/s or 6048 m^3 per day. This showed that 15.54% loss of water was occurring in the lined concrete main canal.

When the result was compared to Renault *et al.*, (2007) about 10 to 15% of loss of water in the canal is admitted, hence the result was not found in the acceptable range. This result was compare with other works having length dependent and soil types. The reasons this losses in the main canal is mainly the sedimentation problem exist in the canal during the site observation. Another reason is unauthorized diversion of water by the farmers into their farm. Again here the conveyance efficiency of the unlined (1149-2084m) trapezoidal main canal is not in the acceptable range according to Renault *et al.*, (2007).This arises due to the growing of weeds, theft of water and sedimentation of the canal. While comparing the two main canals there is a difference in loss of water.

The conveyance efficiency of the secondary canal-1 and canal-2 was found to be 64.71% and 69.23% respectively. The corresponding discharge lost was estimated 0.06m^3/s and 0.04$m^{3/}s$ respectively.

The efficiency of secondary canal-1 is found in the standard and in agreement with (Walker, 1989) 60% and but not with agreement (Brower and Heibloem, 2011) minimum 75% but secondary canal-2 is below the standard value explained by (Walker, 1989) and (Brower and Heibloem, 2011). The reason for this loss in both the secondary canals is due to sedimentation and growing of weeds occurred in the secondary canal section as observed in the field. These figures cannot be considered as acceptable in terms of percentage. This is significant amount of water that could have been used for additional irrigation in the study area.

The loss would have been avoidable with canal lining or minimized with proper maintenance like compaction with clay and other selected materials the canal banks and removing weeds and sediments. The average conveyance efficiency of main and secondary canal is 66.64% and 44.79% respectively.

4.2.2. Application efficiency

Table 4.4 presents summary of the results of application efficiency obtained using the method described in equation (3.5) for head, middle and tail reaches. The estimated application efficiency values were 46.30%, 65.87% and 76.07% at head, middle and tail reaches respectively. This indicates that the head end users are inefficient since apply the excess water to their fields.

Further, looking in to the depth of water applied (Table 4.4) more water was applied by head end test plot (350.67mm) than tail end test plot (208.85 mm). This could rise from the expectation of the farmer that more water means more production. The application efficiency was low, however, high on tail end plots.

The results tend to argue that the application efficiency of tail end users was more efficient than middle and head end users. The middle test plot was more efficient than the head end users. This indicates that those irrigators, who are getting less access to water, were able to efficiently utilize what they have gotten.

The average values of application efficiencies for middle and downstream reaches were within the ranges indicated in many literatures reported for surface irrigation.

For instance, FAO (1989), reported the average application efficiency for surface irrigation in the range of 50 to 60%. Roger *et al.*, (1997) and US (SCS) reported the maximum attainable application efficiency as in range of 50-90% and 55-70% respectively.

Table 4.4: Determinations of application efficiency of the selected plots

Plot Name	Applied depth(mm)	Stored depth Ds(mm)	Ea (%)	Stored depth Ds(mm)	Dreq(mm)	Es (%)
Head	350.67	162.35	46.30	162.35	181.25	89.57
Middle	218.08	143.65	65.87	143.65	159.13	90.27
Tail	208.85	158.88	76.07	158.88	163.24	97.33

Note: Applied depth is determined by dividing volume of water applied to the field by the command area served. Volume of water is determine by flow rate into the field multiplied by the time elapsed. The flow rate to the field is measured by Parshall flume.

4.2.3. Storage efficiency

Water storage efficiency becomes important when water supplies are limited or when excessive time is required to secure adequate penetration of water into the soil. Mean water storage efficiency (Es) computed using equation (3.7) indicate that the storage efficiency of these fields can be regarded as high. Storage efficiency of the head, middle and tail end plots were 89.57%, 90.27% and 97.33% respectively (Table 4.4), with mean value of 92.39%.

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 is sufficient in fulfilling the soil moisture required for good productivity of the crops.

4.2.4. Distribution uniformity

The distribution uniformities of the scheme were found to be 67.68%, 65.95% and 70.32% in the head, middle and tail end fields, respectively with the average value of 67.98%.

FAO (1992), suggested that in an average rotational supply with adequate management and communication, having distribution efficiency (DU) of 65% as "sufficient" and DU of 30% as "poor". Thus, the average values of DU (67.98%) of the scheme indicated the distribution uniformity of irrigation water in the selected farmers' field was sufficient.

4.2.4. Overall irrigation efficiency

The overall efficiency of the scheme was found to be 34.97% equation (3.9). According to FAO (1989), a scheme irrigation efficiency of 50-60% is good, while a scheme irrigation efficiency of below 50% is considered to be poor. In Ethiopia, scheme performance is estimated an average of 36% below design capacity. Small scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew et al., 2010a; 2010b). Hence, the overall efficiency of the scheme indicated the efficiency of the scheme is poor.

4.2.5. Maintenance indicators

4.2.5.1 Water surface elevations ratio (WSER)

This parameter (WSER) was focused on different sections of the main canal. The result would help to predict the impact of sedimentation, weeds and erosion problem on the main canal.

It was computed using equation (3.10) by taking the actual water depth from the canal bottom on different measurement points in each individual inspection location and comparing it with the design water level depth in the main canal. The results are given in Table 4.5 and 4.6. For more refer appendix table 7.2 and 7.3.

Table 4.5: Average WSER of the lined concrete main canal (0-1149m)

Sites	Head		Middle		Tail		Overall	
Average	DWSE	WSER	DWSE	WSER	DWSE	WSER	DWSE	WSER
	0.22	0.90	0.26	0.85	0.3	0.80	0.26	0.85

Table 4.6: Average WSER of the unlined trapezoidal main canal (1149-2084m)

Sites	Head		Middle		Tail		Overall	
Average	DWSE	WSER	DWSE	WSER	DWSE	WSER	DWSE	WSER
	0.14	0.83	0.19	0.76	0.21	0.74	0.18	0.78

Note: the result is based on mean level measurement of water depth at FSL on various main canal sections and all measurements are in meter unit. DWSE is deviation of water surface elevation and WSER is water surface elevation ratio.

As per the design document the intended water level depth in the concrete lined main canal (0-1149m) from the bottom was 1m at full supply level (FSL). The current average water surface elevation at full supply level was found to be 0.85m for lined and 0.78 for unlined trapezoidal section (Appendix table 7.2 and 7.3) respectively. Hence, the overall average WSER was found to be 0.82. This result shows that the main canal was attained about 85% of WSE at FSL and flow depth in the main canal was reduced by 15% from the intended or designed. This arises due to the accumulation of sediments inside the main canal during the site observation.

On the other hand, the average water surface elevation of unlined trapezoidal canal from (1149-2084) was 78%.This shows that the canal the capacity is reduced by 22% from the design water surface elevation. This arises due to the growing of weeds, grasses and sedimentation in the canal. This value is greater than that of lined concrete because of the lined canal has not weeds inside of it.

According to the value of WSER; the head, middle and tail reaches of the main canal during the monitoring period is generally less than one (Table 4.5 and 4.6), this shows that the system performance of the scheme was reduced from the intended. Therefore routine (day to day) maintenance of the main canal is required.

4.2.5.2 Effectiveness of infrastructures

Effectiveness of infrastructure was estimated using equation (3.11). According to the design document, the total number of structures initial installed in the irrigation scheme was 73, however only 45 structures are currently functional. Therefore, the value of effectiveness of infrastructure is found to be 61.64%. This value indicates that more than 38.36% of initially installed structures were non-functional and the physical irrigation infrastructure in this system has deteriorated over time. It was happing due to absence of regular repair of the irrigation system components.

Table 4.7: Effectiveness of infrastructure (EI) of the scheme

No	Name of structure	Installed	Functional	Non-functional	EI (%)
1	Weir	1	1	0	100
2	Off take gate	1	1	0	100
3	Drop structures	6	3	3	50
4	Division box	15	10	5	33.33
5	Road crossing culvert	2	2	0	100
6	Division box gates	34	18	16	47.05
7	Turnout	14	10	4	28.57
8	Total	73	45	28	61.64

4.2.5.3 Sustainability of irrigated area

This indicator empowered to investigate the alterations or change in area actually irrigated against the planned in terms of ratio and provide valid reasons for such variation (Raghava, *et al.*, 2011). As per the design document, the intended command area that a scheme could potentially irrigate is about 185ha, however the actual irrigated area in a cropping season is 120ha. Hence, sustainability of irrigation is found to be 64.86% using equation (3.12). This indicates that the actual irrigated area in a cropping season was remains 64.86% of the design/ intended command area. Therefore, irrigated area of the scheme was decreased by 35.14% compared with the planned.

This result shows that the inability of the scheme water supplied to the irrigated area and inadequate maintenance activity is not limiting factors for poor system performance; it implies that this parameter will be not intensifying the maintenance requirements of the system. This result was agreed by Mekonen and Mamuye (2015), authors reported that, reductions in command area from the intended are not due to the inability of the scheme water supplied to the farm and lacking of maintenance activity (Melisew, 2012).

4.3. Evaluation of farmers perception

The perception of the farmers with regard to scheme performance were conducted by interviewing 91 beneficiary farmers/households.

The questions focused on the maintenance activity, water management of the scheme. Respondents were selected from head, middle and tail reaches of the scheme.

There is a water users association in the kebele which was established in 2012 with 22 male and 5 female members. From the water users association, water committee or ye “wuha abat” were selected based on the number of canals to manage the overall activity related to water usage. The farmers laid in one canal would have one “Wuha Abat” (leader) who is responsible for managing his/her member.

“Wuha Abats” are accountable for the chairman of the association. The objective of wuha abats are for greater user commitment, which can lead to more effective use of the resources by helping to overcome many of the problems that public irrigation systems face, such as inequitable water distribution, inefficiency and poor operation and maintenance activity.

A) Water management

The beneficiaries manage the water distribution in the scheme without the designed schedule of irrigation. From the respondents, 24.18% and 75.82% confirmed that distribution is managed by water user association and beneficiary farmers/household’s based on their irrigation schedule respectively (Table 4.8).

The household with the rotation will use the water for that day until he/she completes irrigating the fields. The beneficiaries in the scheme do not know in advance when they will get water. 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 12hrs. This showed that the water user association is not legally recognized and lack of power to discharge its responsibilities (to enact regulations that are legally binding on its member) and maintenance obligation are impeding their effectiveness. This has reduced the overall performance and sustainability of Golina irrigation scheme.

Table 4.8: Decision on the schedule of irrigation

Who decides on how much and when to irrigate	Number of Respondents	Percent
WUA	22	24.18
Kebele Administration	0	0
Beneficiary Households/farmers	69	75.82
Total	91	100

The system operates starting from March to end of June and October to February. During rainy season (July to September) main intake is closed and the water is made to flow through its natural course until there is claim of irrigation water in the scheme.

Table 4.9: Response of households/farmers on the criteria to decide when to irrigate

What criteria do you use to decide when to irrigate	Number of Respondents	Percent
Wait until crops leaves wilt	34	37.36
Check the soil near the roots	51	56.04
When it becomes dry irrigate everyday	6	6.59
Total	91	100

Table 4.9 above shows that 37.36% of the respondents replied that they will wait until the crops leaves wilt, 56.04% of the respondents replied that they irrigate their crop when the soil near the crop roots is dry; and 6.59% of the respondents replied that they will when it is dry (table 4.9).

B) Sustainability

For sustainability of the scheme, one of the important steps in irrigation system design has been farmers' participation in all stages of the project cycle.

However, the government has been making huge investments 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 activity of the scheme as a whole. Thus, 89.01% of the respondents confirmed that they do not undertake even minor maintenance of the scheme (Table 4.10).

Table 4.10: Responses related to maintenance activity

Have you participated in maintenance of irrigation scheme	Number of Respondents	Percent
Yes	10	10.99
No	81	89.01
Total	91	100

C) Conflict and Conflict Resolution Mechanisms

Conflict between and among the beneficiaries and the downstream farmers who are not served by the canal water was said to be widespread. The conflicts were solved by arbitration in most of the cases and the remaining few were through legal procedure by law.

Table 4.11: Beneficiary conflicts

Is there any conflict on the use of irrigation scheme	Number of Respondents	Percent
Yes	86	94.51
No	5	5.49
Total	91	100

Table 4.11 above shows that 94.51% of household respondents believe that the conflict is due to the problem of water management which is lack of responsible body to control the water distribution system.

Table 4.12: Source of conflict in the irrigation scheme

What are the common sources of conflict in the scheme	Number of Respondents	Percent
Water shortage	42	46.15
Land shortage	20	21.99
Water theft	19	20.88
Water management problem	10	11.11
Others	0	0
Total	91	100

Table 4.13: Response of households on equal availability of water to users

Is water equally available to all users in the scheme?	Number of Respondents	Percent
Yes	10	11.11
No	81	89.89
Total	91	100

D) Support Services

According to the respondents there is no strong body (WUA) that can materialize the bylaws and enforce their legislation. This shows that there is no institutional support on different technologies and agricultural inputs as per the schedule of their irrigation practice.

But all of the respondents use improved inputs. The institutional service has to be improved to make the scheme sustainable for better performance.

Table 4.14: Access to improved technology

Do you use different improved inputs	Number of Respondents	Percent
Yes	91	100
No	0	0
Total	91	100

E) 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 imperative. It was, however, learned that farmers were not getting advice from an irrigation agronomist or from a qualified development agent. There were no organizations committed towards providing farmers with the needful training and extension services. About 90.11% beneficiary respondents have not got adequate capacity building training on overall operation, utilization and management of irrigation scheme (Table 4.15). 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 suitable.

Table 4.15: Response of households on the capacity building trainings

Were there any training given to you before the scheme handover?	Number of Respondents	Percent
Yes	9	9.89
No	82	90.11
Total	91	100

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In this study, an attempt was made to evaluate the performance of Golina small-scale irrigation scheme at, Amhara National Regional State (ANRS), north Wollo zone, kobo wereda and Abuare kebele using performance and maintenance indicators. Performance evaluation of irrigation scheme plays a vital role in improving the efficiency of the system by providing information to the beneficiaries required for maintenance, how to improve their systems and management practices. It helps to identify problems and management practice of irrigation scheme.

The primary data were collected for this study includes, canal discharge measurement, observation of irrigation structures, measurement of discharge applied for the selected farm fields, water level at different points in the main canal and determination of soil moisture contents of the soil of the selected irrigation fields before and two days after irrigation by taking soil samples at different depths. Secondary data were design document and number of households. Generally, the study was more of primary data intensive.

The total length of the main canal of the scheme is 2084m. From this 1149m lined concrete rectangular and 935m earthen trapezoidal section. Average conveyance efficiencies were 84.44% and 78.95% for lined rectangular and earthen trapezoidal respectively. The scheme has also two secondary canals.

The study showed that the average application efficiencies of head, middle and tail end of selected fields were 46.30%, 65.87% and 76.07%, respectively. Storage efficiency of the scheme varies between 89.57% and 97.33% with mean value of 92.39%. Similarly the distribution uniformities of the scheme were found to be 67.68%, 65.95% and 70.32% in the head, middle and tail end fields, respectively with the average value of 67.98%. Maintenance performance indicators were considered the parameter of water surface elevation ratio, effectiveness of infrastructure and sustainability of irrigable area. Generally, it was found that the maintenance performance of the system was very poor.

Questionnaire-based interviews conducted to know the farmers' perception on the performance of the scheme. It were focused on water management activity, maintenance activity ownership level of the scheme, irrigation scheduling, sources of conflict and others. The study revealed that the level of participation is visible from the farmers' willingness to contribute to the project activities in terms of commitment of time, labor and material resources.

In general, based on the assessment carried out, it can be concluded that improvement measures should be taken to improve the performance of the scheme. As there is no shortage of water, the schemes have room to expand and to provide irrigation opportunities to the surrounding community relying on rain fed agriculture. The comparison of the performance of irrigation system will help to know the present status of these system. Therefore, for the improvement of the irrigation system management and the irrigation practice frequent performance evaluation is very important.

According to the results obtained, water management practice of the scheme was generally poor. This however can be improved by sharing experience from different irrigation scheme which has a good performance.

5.2. Recommendation

The following recommendations are drawn base on the study result:

- ✓ Regular training on over all irrigation water management, scheme operation and maintenance should be given to beneficiary farmers.
- ✓ Institutional support, 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 maintenance of the scheme.
- ✓ Empowerment of the water user association is fundamental for irrigation scheme sustainability. Hence, water user association of Golina irrigation scheme has to be further strengthened. Effort should also be made to bring all beneficiaries of the irrigation scheme under one water user association.
- ✓ Hydraulic flow measuring structures should be constructed at different levels of the canals. It will help to monitor the activities in relation to water utilization and irrigation efficiencies as well.
- ✓ It is strongly advisable to provide a night storage to expand the command area and to make the farmers more beneficiary than the existing situation. Hence the water flows during the night time.

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7. APPENDICES

7.1. Appendix tables

Appendix table 7. 1: Indicative values of soil moisture content at saturation, at Field Capacity (FC) and Permanent Wilting Point (PWP)

Textural class	θ_{sat} [$m^3\ m^{-3}$]	θ_{FC} [$m^3\ m^{-3}$]	θ_{WP} [$m^3\ m^{-3}$]
Sandy soils: coarse-textured soils			
Sand	0.32 – 0.42	0.10 – 0.15	0.03 – 0.06
Loamy sand	0.32 – 0.47	0.12 – 0.18	0.04 – 0.10
Loamy soils: moderately coarse-textured soils			
Sandy loam	0.34 – 0.51	0.17 – 0.26	0.06 – 0.13
Loamy soils: medium textured soils			
Loam	0.42 – 0.51	0.22 – 0.31	0.09 – 0.16
Silt loam	0.42 – 0.55	0.23 – 0.34	0.08 – 0.15
Silt	0.42 – 0.55	0.30 – 0.32	0.09 – 0.11
Loamy soils: moderately fine-textured soils			
Sandy clay loam	0.40 – 0.49	0.20 – 0.30	0.13 – 0.19
Clay loam	0.47 – 0.51	0.28 – 0.38	0.16 – 0.22
Silty clay loam	0.49 – 0.53	0.32 – 0.40	0.16 – 0.23
Clayey soils: fine textured soils			
Sandy clay	0.47 – 0.53	0.28 – 0.40	0.20 – 0.30
Silty clay	0.49 – 0.55	0.38 – 0.50	0.22 – 0.36
Clay	0.51 – 0.58	0.39 – 0.55	0.30 – 0.45

Source (FAO, 1998)

Appendix table 7. 2: Lined main canal water surface elevation ratio

Main Canal Water Surface Elevation Ratio(Main Canal) 0-1149 lined concrete																	
Head						Middle						Tail					
Lo No1	Ch.Le(m)	IWSE(m)	AWSE	Dev.WSE	WSER	Lo No2	Ch.Le(m)	IWSE(m)	AWSE	Dev.WSE	WSER	Lo No3	Ch.Le(m)	IWSE(m)	AWSE	Dev.WSE	WSER
L1	10	1	0.8	0.2	0.80	L40	400	1	0.761	0.239	0.76	L79	790	1	0.722	0.278	0.72
L2	20	1	0.799	0.201	0.80	L41	410	1	0.76	0.24	0.76	L80	800	1	0.721	0.279	0.72
L3	30	1	0.798	0.202	0.80	L42	420	1	0.759	0.241	0.76	L81	810	1	0.72	0.28	0.72
L4	40	1	0.797	0.203	0.80	L43	430	1	0.758	0.242	0.76	L82	820	1	0.719	0.281	0.72
L5	50	1	0.796	0.204	0.80	L44	440	1	0.757	0.243	0.76	L83	830	1	0.718	0.282	0.72
L6	60	1	0.795	0.205	0.80	L45	450	1	0.756	0.244	0.76	L84	840	1	0.717	0.283	0.72
L7	70	1	0.794	0.206	0.79	L46	460	1	0.755	0.245	0.76	L85	850	1	0.716	0.284	0.72
L8	80	1	0.793	0.207	0.79	L47	470	1	0.754	0.246	0.75	L86	860	1	0.715	0.285	0.72
L9	90	1	0.792	0.208	0.79	L48	480	1	0.753	0.247	0.75	L87	870	1	0.714	0.286	0.71
L10	100	1	0.791	0.209	0.79	L49	490	1	0.752	0.248	0.75	L88	880	1	0.713	0.287	0.71
L11	110	1	0.79	0.21	0.79	L50	500	1	0.751	0.249	0.75	L89	890	1	0.712	0.288	0.71
L12	120	1	0.789	0.211	0.79	L51	510	1	0.75	0.25	0.75	L90	900	1	0.711	0.289	0.71
L13	130	1	0.788	0.212	0.79	L52	520	1	0.749	0.251	0.75	L91	910	1	0.71	0.29	0.71
L14	140	1	0.787	0.213	0.79	L53	530	1	0.748	0.252	0.75	L92	920	1	0.709	0.291	0.71
L15	150	1	0.786	0.214	0.79	L54	540	1	0.747	0.253	0.75	L93	930	1	0.708	0.292	0.71
L16	160	1	0.785	0.215	0.79	L55	550	1	0.746	0.254	0.75	L94	940	1	0.707	0.293	0.71
L17	170	1	0.784	0.216	0.78	L56	560	1	0.745	0.255	0.75	L95	950	1	0.706	0.294	0.71
L18	180	1	0.783	0.217	0.78	L57	570	1	0.744	0.256	0.74	L96	960	1	0.705	0.295	0.71
L19	190	1	0.782	0.218	0.78	L58	580	1	0.743	0.257	0.74	L97	970	1	0.704	0.296	0.70
L20	200	1	0.781	0.219	0.78	L59	590	1	0.742	0.258	0.74	L98	980	1	0.703	0.297	0.70
L21	210	1	0.78	0.22	0.78	L60	600	1	0.741	0.259	0.74	L99	990	1	0.702	0.298	0.70
L22	220	1	0.779	0.221	0.78	L61	610	1	0.74	0.26	0.74	L100	1000	1	0.701	0.299	0.70
L23	230	1	0.778	0.222	0.78	L62	620	1	0.739	0.261	0.74	L101	1010	1	0.7	0.3	0.70
L24	240	1	0.777	0.223	0.78	L63	630	1	0.738	0.262	0.74	L102	1020	1	0.699	0.301	0.70
L25	250	1	0.776	0.224	0.78	L64	640	1	0.737	0.263	0.74	L103	1030	1	0.698	0.302	0.70
L26	260	1	0.775	0.225	0.78	L65	650	1	0.736	0.264	0.74	L104	1040	1	0.697	0.303	0.70
L27	270	1	0.774	0.226	0.77	L66	660	1	0.735	0.265	0.74	L105	1050	1	0.696	0.304	0.70
L28	280	1	0.773	0.227	0.77	L67	670	1	0.734	0.266	0.73	L106	1060	1	0.695	0.305	0.70
L29	290	1	0.772	0.228	0.77	L68	680	1	0.733	0.267	0.73	L107	1070	1	0.694	0.306	0.69
L30	300	1	0.771	0.229	0.77	L69	690	1	0.732	0.268	0.73	L108	1080	1	0.693	0.307	0.69
L31	310	1	0.77	0.23	0.77	L70	700	1	0.731	0.269	0.73	L109	1090	1	0.692	0.308	0.69
L32	320	1	0.769	0.231	0.77	L71	710	1	0.73	0.27	0.73	L110	1100	1	0.691	0.309	0.69
L33	330	1	0.768	0.232	0.77	L72	720	1	0.729	0.271	0.73	L111	1110	1	0.69	0.31	0.69
L34	340	1	0.767	0.233	0.77	L73	730	1	0.728	0.272	0.73	L112	1120	1	0.689	0.311	0.69
L35	350	1	0.766	0.234	0.77	L74	740	1	0.727	0.273	0.73	L113	1130	1	0.688	0.312	0.69
L36	360	1	0.765	0.235	0.77	L75	750	1	0.726	0.274	0.73	L114	1140	1	0.687	0.313	0.69
L37	370	1	0.764	0.236	0.76	L76	760	1	0.725	0.275	0.73	L114.9	1149	1	0.686	0.314	0.69
L38	380	1	0.763	0.237	0.76	L77	770	1	0.724	0.276	0.72						
L39	390	1	0.762	0.238	0.76	L78	780	1	0.723	0.277	0.72						
Avg			**0.78**	**0.22**	**0.90**				**0.74**	**0.26**	**0.85**				**0.70**	**0.30**	**0.80**
Max			**0.8**	**0.238**	**0.80**				**0.761**	**0.277**	**0.76**				**0.722**	**0.314**	**0.72**
Min			**0.762**	**0.2**	**0.76**				**0.723**	**0.239**	**0.72**				**0.686**	**0.278**	**0.69**

Appendix table 7. 3: Unlined main canal water surface elevation ratio

Main Canal Water Surface Elevation Ratio(Main Canal) 1149-2084 unlined trapezoidal section

Head						Middle							Tail				
Lo No1	Ch.Le(m)	IWSE(m)	AWSE	Dev.WSE	WSER	Lo No2	Ch.Le(m)	IWSE(m)	AWSE	Dev.WSE	WSER	Lo No 3	Ch.Le(m)	IWSE(m)	AWSE	Dev.WSE	WSER
L115	1159	0.8	0.686	0.114	0.858	L147	1569	0.8	0.635	0.165	0.793	L179	1789	0.8	0.587	0.213	0.734
L116	1169	0.8	0.684	0.116	0.855	L148	1579	0.8	0.633	0.167	0.791	L180	1799	0.8	0.586	0.214	0.732
L117	1179	0.8	0.683	0.117	0.853	L149	1589	0.8	0.632	0.168	0.790	L181	1809	0.8	0.585	0.215	0.732
L118	1189	0.8	0.681	0.119	0.851	L150	1599	0.8	0.630	0.170	0.788	L182	1819	0.8	0.585	0.215	0.731
L119	1199	0.8	0.679	0.121	0.849	L151	1609	0.8	0.628	0.172	0.786	L183	1829	0.8	0.584	0.216	0.730
L120	1209	0.8	0.677	0.123	0.847	L152	1619	0.8	0.627	0.173	0.784	L184	1839	0.8	0.584	0.216	0.730
L121	1219	0.8	0.676	0.124	0.845	L153	1629	0.8	0.625	0.175	0.782	L185	1849	0.8	0.583	0.217	0.729
L122	1229	0.8	0.674	0.126	0.843	L154	1639	0.8	0.624	0.176	0.780	L186	1859	0.8	0.583	0.217	0.728
L123	1239	0.8	0.672	0.128	0.840	L155	1649	0.8	0.622	0.178	0.778	L187	1869	0.8	0.582	0.218	0.728
L124	1249	0.8	0.671	0.129	0.838	L156	1659	0.8	0.621	0.179	0.776	L188	1879	0.8	0.582	0.218	0.727
L125	1259	0.8	0.669	0.131	0.836	L157	1669	0.8	0.619	0.181	0.774	L189	1889	0.8	0.581	0.219	0.726
L126	1269	0.8	0.667	0.133	0.834	L158	1679	0.8	0.618	0.182	0.772	L190	1899	0.8	0.581	0.219	0.726
L127	1279	0.8	0.666	0.134	0.832	L159	1689	0.8	0.616	0.184	0.770	L191	1909	0.8	0.580	0.220	0.725
L128	1289	0.8	0.664	0.136	0.830	L160	1699	0.8	0.614	0.186	0.768	L192	1919	0.8	0.580	0.220	0.725
L129	1299	0.8	0.662	0.138	0.828	L161	1709	0.8	0.613	0.187	0.766	L193	1929	0.8	0.579	0.221	0.724
L130	1309	0.8	0.661	0.139	0.826	L162	1719	0.8	0.611	0.189	0.764	L194	1939	0.8	0.579	0.221	0.723
L131	1319	0.8	0.659	0.141	0.824	L163	1729	0.8	0.610	0.190	0.762	L195	1949	0.8	0.578	0.222	0.723
L132	1329	0.8	0.657	0.143	0.822	L164	1739	0.8	0.608	0.192	0.760	L196	1959	0.8	0.578	0.222	0.722
L133	1339	0.8	0.656	0.144	0.820	L165	1749	0.8	0.607	0.193	0.759	L197	1969	0.8	0.577	0.223	0.721
L134	1349	0.8	0.654	0.146	0.818	L166	1759	0.8	0.605	0.195	0.757	L198	1979	0.8	0.576	0.224	0.721
L135	1359	0.8	0.653	0.147	0.816	L167	1769	0.8	0.604	0.196	0.755	L199	1989	0.8	0.576	0.224	0.720
L136	1369	0.8	0.651	0.149	0.814	L168	1779	0.8	0.602	0.198	0.753	L200	1999	0.8	0.575	0.225	0.719
L137	1379	0.8	0.649	0.151	0.812	L169	1789	0.8	0.601	0.199	0.751	L201	2009	0.8	0.575	0.225	0.719
L138	1389	0.8	0.648	0.152	0.810	L170	1799	0.8	0.599	0.201	0.749	L202	2019	0.8	0.574	0.226	0.718
L139	1399	0.8	0.646	0.154	0.808	L171	1809	0.8	0.598	0.202	0.747	L203	2029	0.8	0.574	0.226	0.717
L140	1409	0.8	0.644	0.156	0.805	L172	1819	0.8	0.596	0.204	0.745	L204	2039	0.8	0.573	0.227	0.716
L141	1419	0.8	0.643	0.157	0.803	L173	1829	0.8	0.595	0.205	0.743	L205	2049	0.8	0.567	0.233	0.709
L142	1429	0.8	0.641	0.159	0.801	L174	1839	0.8	0.593	0.207	0.742	L206	2059	0.8	0.561	0.239	0.702
L143	1439	0.8	0.640	0.160	0.799	L175	1849	0.8	0.592	0.208	0.740	L207	2063	0.7	0.600	0.100	0.857
L144	1449	0.8	0.638	0.162	0.797	L176	1859	0.8	0.590	0.210	0.738	L208	2073	0.7	0.594	0.106	0.849
L145	1459	0.8	0.636	0.164	0.795	L177	1869	0.8	0.589	0.211	0.736	L208.4	2084	0.7	0.588	0.112	0.840
L146	1469	0.8	0.635	0.165	0.793	L178	1879	0.8	0.587	0.213	0.734						
Average			**0.660**	**0.140**	**0.825**				**0.611**	**0.189**	**0.763**				**0.580**	**0.210**	**0.736**
Maximum			**0.686**	**0.165**	**0.858**				**0.634781**	**0.212613**	**0.793**				**0.600**	**0.239**	**0.857**
Minimum			**0.635**	**0.114**	**0.793**				**0.587**	**0.165**	**0.734**				**0.561**	**0.100**	**0.702**

7.2. Appendix figures

Appendix figure 7. 1: Determination of soil textural class

Appendix figure 7. 2: Un-functional drop structure

Appendix figure 7. 3: Un-functional gates at division boxes and turnouts

Appendix figure 7. 4: overtopping and weeds growth in conveyance system

Appendix figure 7. 5: Water flow rate measurement device (Parshall flume)

Appendix figure 7. 6: Main canal water losses (on earth canal)

Appendix figure 7. 7: Water stressed onion crops

Appendix figure 7. 8: Alignment of Parshall flume

Appendix figure 7. 9: Field discharge measurement by Parshall flume

Appendix figure 7. 10: The diversion structure (weir)

7.3. Questionnaires

Sample questionnaires for performance evaluation of Golina small-scale irrigation scheme:

Name……………………………………………… Age............Sex.................

Project Name..

1. Who decides how much to irrigate?

A) Water user association B) Kebele administration C) yours own D) wereda administrations

2. What criteria you used to irrigate the crop?

A) Waiting until crop leaves wilt B) checking the soil near the roots C) when it is dry D) Irrigate every day E) Based on the schedule set by water user association

3. Have you ever participated in any maintenance activity of the scheme?

A) Yes B) No

4. For question number 3, if no why? Specify activities you participated……………………...
   ……………………………………………………………………………………………
   ………………………………………………………………………………………….................
   ....
   ....

5. Is there any conflict among water users?

A) Yes B) No

6. For question number 5, if yes what are the causes for conflict?

A) Water shortage B) Water theft C) Uneven distribution of water

7. Do you think the project is important for you?

A) Yes B) No

8. Have you taken any training activity about wise use of water?

A) Yes B) No

9. For question 8, if no why?……………………………………..……………………...
……………………………………………………………………………………………
……………………………………………………………………………………......

10. Who is responsible to keep the infrastructures of the scheme from damage?

A) Federal government B) Regional government C) Zone administration C) Wereda administration

D) Kebele administration E) Beneficiary of the scheme

11. What is the system of water allocation?

A) Proportional to the amount of land you have under irrigation.

B) Equal division among members of the association

C) Based on reach of the water sources

D) First come first serve

12. For question 11, Specify if any other system?...
....
....
....