PERFORMANCE EVALUATION OF GOLINA SMALL SCALE IRRIGATIO SCHEME (RAYA KOBO), ETHIOPIA

M. Sc. THESIS

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DEDICATION

I dedicate this thesis manuscript to all my families for their love and dedicated partnership in the success of my love.

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STATEMENT OF THE AUTHOR

First of all, I declare that this thesis is my work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for the master degree of science in Dam engineering at the Hawassa University Institute of technology. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of the source is made.

Sisay Ayalew Negash Signature: ____________________

Hawassa University, Ethiopia October, 2017

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ABBREVIATIONS

ACSI	Amhara Credit and Saving Inistitution
ANRS	Amhara National Regional State
ANRSWR	Amhara National Regional State Water Bureau
CO-SAERAR	Commission for Sustainable Agriculture and Environmental Rehabilitation in Amhara Region
CWR	Crop Water Requirement
DA	Development Agent
d_{req}	depth required
Ea	Application Efficiency
Ec	Conveyance efficiency
ES	Storage Efficiency
ET	Evapotranspiration
ETC	Crop Evapotranspiration
FAO	Food and Agricultural Organization
FC	Field Capacity
ha	Hectare
ICID	International Commission on Irrigation and Drainage
ILRI	International Livestock Research Institute
IWR	Irrigation Water Requirement
KC	Crop Coefficient
KGVDP	Kobo Girana Valley Development Program
Masl	Meter above sea level
MC	Main Canal
MoWR	Ministry of Water Resources
NGO	Non-Governmental Organization
P	Depletion fraction
PWP	Permanent Wilting Point
RAW	Readily Available Water
SARC	Serinka Agricultural Reasurch Center

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SC	Secondary Canal
SCS	Soil Conservation Service
TAW	Total Available Water
UNDP	United Nation Development Program
US	United State
USDA	United state department of agriculture
WUA	Water user Association
Zr	Root depth

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ABSTRACT

This study was initiated to assess and evaluate the performance of Golina small scale irrigation scheme using internal performance indicators (conveyance efficiency, application efficiency, storage efficiency and distribution uniformity) so as to recommend appropriate measures to improve the scheme management and performance. To undertake this study primary data (discharge measurements in the canals, measurement of depth 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 were collected. As to the water delivery service, the scheme was designed to deliver irrigation water to individual fields based on proportional flows throughout the irrigation season, but actual water delivery service to irrigators was unknown date and volume. It was found that the conveyance efficiencies of main canal one and two were 73.3% and 79.57% respectively. The conveyance efficiencies of the secondary canals one to six were 57%, 79%, 80%, 78.8%, 57.4% and 72% respectively. The application efficiency result on three spots in farmers' field located at head, middle and tail reaches of the command were found to be 48.26%, 68.51% and 75.65% respectively. This shows that the conveyance efficiency of the main and secondary canals one and five and the head plot application efficiency were found to be below the expected level. Based on the assessment of farmer's perception about the performance of the irrigation scheme it is found that all respondents confirmed that though the establishment of the scheme is very important for them to secure food self-sufficiency, they feel that it is not performing well. The household respondents believe major problems that make the scheme inefficient were maintenance problem (27.1%), water theft or unauthorized canal breaching in the scheme (20.8%), water shortage (18.7%) and water utilization conflict (12.5%). Generally the overall performance of the scheme is rated as poor. It indicates that irrigators need technical support and follow up in area of on-farm water management, canal maintenance, and institutional support in terms of facilitating services and access to market so as to farther strengthen.

Key words: Irrigation performance, applied depth, uniformity and application

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1. INTRODUCTION

1.1. Background

Food security in developing nations is aggravated by the rapid population growth and the consequent demand for food. Exacerbating this increased food demand, there has been a significant rise in prices of food products in the world market. Consequently, to better meet the demand for food and reduce the impact of inflated food prices, substantial investments in modifying existing farming systems or establishing new ones will be necessary (FAO,1997

Many parts of Ethiopia have faced food insecurity for the past three decades. In addition to and as a consequence of increases in population, continuous land degradation, excessive deforestation, erratic and unreliable rainfall and other factors have eroded assets and crippled coping mechanisms of farm households. Recurrent drought has had a long lasting effect on the livelihood of agricultural communities and the whole economy. As a result, both acute and chronic hunger and malnutrition occur among many Ethiopians even when there are good harvests during normal times (Catterson et al., 1999).

As a dramatic change to a mostly rain-dependent farming system, irrigated agriculture was thought to be one of the solutions to enhance food security in the country. Since its initial promotion, irrigated agriculture in Ethiopia still only comprises a small fraction of total cultivated area; of the 4.3 million hectares that can be irrigated, only 247,470 ha are irrigated. From this irrigated area, 56% are traditional schemes, 19% are small-modern scale schemes and 25% covered by medium to large modern scale schemes (Tilahun and Paulos, 2004).

As a regional strategy of water resources development, irrigated agriculture has become the main intervention to mitigate recurrent drought and thereby improve food security and income of the rural population in Amhara Region (ANRSWB, 2005). Although Amhara encompasses four river basins, traditional to modern irrigation covers less than 2% of 0.57 million ha, the total irrigable area in the region. Currently, more than 6,200 small scale irrigation schemes of which 95% are traditional exist in the region. Furthermore, modern schemes cover only 1.4% of the potentially irrigated area. Interestingly, the irrigation schemes are owned by more than

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330,000 households (or more than 1.9 million people) with an average irrigated land holding of 0.2 ha.

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.

The lack of operation autonomy and little sense of ownership on the parts of the beneficiaries are common problems in the majority of small-scale irrigation schemes. This would be attributed to the large number of small scale irrigation schemes in the country whose efficiencies were not evaluated to enhance productivity. Lack of time, budget, research personnel, and accessibility of the schemes are few of the problems to this. The Golina irrigation scheme is one of them whose performance is not evaluated and this study is going to address the issue.

For example, water use efficiencies in developing countries are typically 30-50%, and in some areas, only 20-30%. Yet few effective water conservation programs exist, and most countries do not monitor irrigation system performance and management (Hennessy, 1993). Furthermore, water shortages have become more frequent and farmers often face deficiencies in water deliveries, resulting in reduced yields and incomes. Poor management of available water for irrigation, both at system and farm levels, has led to a range of problems and further aggravated water availability and has reduced the benefits of irrigation investments (FAO, 1996).

According to James (1988), farm irrigation systems are designed and operated to supply the individual irrigation requirements of each field on the farm while controlling deep percolation, runoff, evaporation, and operational losses. The performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed, and applied, and by the

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adequacy and uniformity of application in each field on the farm. Consequently, optimal water use efficiency in any irrigation system depends on maximizing water use efficiency, maintaining good water quality and preventing salinization of irrigation water and these require improved quality and reliable water delivery to the field (Burt and Styles, 1999).

Field evaluations of irrigation schemes or systems play a fundamental role in generating information and data to improve surface irrigation systems (Pereira and Trout (1999) as cited in Solomon (2006)). Evaluations result in an estimate of the efficiency of the system as it is being used, a measure of how effectively the system can be operated and whether it can be improved, information that will assist engineers to design other systems and comparison of various methods, systems, and operating procedure as a base for economic decisions. Finally, these results can be used to offer effective advice to the irrigators on how to improve their systems and management practices.

Improving the performance of a furrow irrigation system requires more than achieving high distribution uniformity. The other primary measure of irrigation performance, application efficiency, is just as important. A uniform irrigation does not guarantee efficiency, and an efficient irrigation need not be uniform. The efficiency of furrow irrigation is about 60 %, which means that 40 % of the given water is lost due to runoff and percolation. The performance of irrigation operation should be evaluated periodically, both at the system- and at farm-levels, using indicators that have been established. Hence, this study was evaluated the performance of Golina small scale irrigation schemes.

1.2. Statement of the problem

Amhara region is one of the regions in the country with vast potential for irrigation development. In the region more than 86% of the irrigated land is served by traditional schemes. The traditional irrigation belongs to those schemes that are designed, developed and operated by farmers themselves. Farmer have developed different water management technologies applying their indigenous knowledge of crop characteristics, soil condition, topography, climate, hydrology and social values that allowed them to live under harsh conditions. These technologies involve designing and development of diversion structures,

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designing of irrigation canals, crossing of big gullies, developing appropriate cropping pattern, equitable sharing of water, conflict resolve and moisture conservation techniques.

This wealth of practices helped the farmers to utilize traditional irrigation schemes for century old in sustainable way while most of the modern schemes are not functioning well as planned. Farmers innovations in traditional irrigation schemes are therefore, quite important to be considered in designing, operation and maintenance of modern irrigation schemes. There are a number of constraints that have been responsible for a slow rate of development and underperformance of irrigation.

Field researches highlighted substantial shortcomings in management (operation and maintenance), equity, cost recovery and agricultural productivity. One of the reasons for the failure and un-sustainability of irrigation projects in Eastern Amhara has been institutional and management deficiencies. 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).

Poor system management and service provision, poor understanding of farmer priorities and inadequate markets, lack of clear and sustainable water rights accorded to users, at on individual or group level and lack of transparent accountability of and authority vested in the managing organizations were the major factors among others that account for under performance of irrigation schemes.

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1.3. Objective of the study

General Objective

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

Specific Objectives

- To quantify the conveyance efficiency, distribution uniformity, application efficiency and storage efficiency
- To assess the impact of the delivery system on the overall irrigation efficiency
- To assess farmers' perception about scheme performance

1.4. Scope of the study

This study focus on the performance evaluation of Golina furrow irrigation scheme to evaluate the irrigation system and practice using performance indicators such as application efficiency, distribution uniformity, conveyance efficiency and storage efficiency by taking necessary data or information at the selected farms.

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2. LITERATUREREVIEW

2.1. 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 to 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 percent 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).

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

2.2. Ethiopian Irrigation Development Profile

Modern water development schemes are a relatively new phenomenon in the country. The imperial government took the first initiatives in water resource development in the second half of the 1950s. Large scale water projects for agricultural purpose and power generation were constructed from the end of 1950s, and were constructed in the Awash valley as part of the agro-industrial enterprises that were expanding in the area at that time. They subsequently spread to the Rift valley and the Wabe shebelli basin. Essentially, the government's interest at that time centered entirely on large-scale and high technology water projects: hydro-power dams, irrigation schemes and water supply projects for Addis Ababa and a few major towns.

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 1970s and 1980s; 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

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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).

2.3. Surface Irrigation System

The term 'surface irrigation' refers to abroad class of irrigation methods in which water is distributed over the field by overland flow. A flow is introduced at one edge of the field and covers the field gradually. The rate of coverage (advance) is dependent almost entirely on the difference between the discharge onto the field and the accumulated infiltration into the soil. Secondary factors include field type, surface roughness, and the geometry or shape of the flow cross-section (FAO, 1989). Recently, the International Commission on Irrigation and Drainage (ICID, 2002) defined the term surface irrigation as a method of irrigation where the water is applied to the land by allowing it to flow over the soil surface, as it advances and infiltrates. Surface irrigation includes various methods such as furrow, level basin, and border.

The practice of surface irrigation is thousands of years old. It collectively represents perhaps as much as 95% of common irrigation activity (Walker, 1989). In another report, Pereira (1997) stated that surface irrigation may largely exceed 87.5 % in the Near East and 85% in Africa of the total irrigated area.

Surface irrigation is widely utilized and local irrigators generally have at least a minimal understanding of how to operate and maintain the system. In addition, surface system are often more acceptable to agriculturists who appreciate the effects of water shortage on crop yields since it appears easier to apply the depth required to refill the zone. Surface irrigation systems can be developed at farm level with minimum capital investment.

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Basin irrigation- Basin irrigation method is divided into level rectangular areas bounded by dikes or ridges to prevent runoff, and provides an undirected flow of water on to the field. Water is turned in at one or more points until the desired gross volume has been applied to the area. The flow rate must be large enough to cover the entire basin in approximately 60 to 70 percent of the final required for the soil to absorb the desired amount of water. Water is pounded until infiltrated. If the basins are small or if the discharge rate available is relatively large, there are few soils not amendable to the basin irrigation. Generally, however, moderate to slow intake soils and deep-rooted and closely spaced crops favors basin irrigation.

Border irrigation- In many circumstances, border irrigation can be viewed as an expansion of basin irrigation to include long rectangular or contoured field shape, longitudinal but no lateral slope and free draining conditions at the lower end. The border strip is an area of land flanked by two border ridges, dikes, or ditches. These ditches guide the irrigation stream from a point or points where the water is applied to the ends of the strip. The border ditch system uses a ditch as a divider between individual strips. The ditch carries irrigation water that is applied at different locations along the entire length of the field. The border dike system uses dikes on both sides of the strip and the irrigation water is supplied only at the upper end of the strip.

Furrow irrigation- The most common type of irrigation method is furrow irrigation, which is carried out using small channels or furrows that run along or across the contour depending on the principal slope of the land. Water introduced in these "furrows," "creases," or "corrugations" infiltrates through the wetted perimeter and moves vertically and laterally thereafter to refill the soil. Furrow can be used in conjunction with the basins and borders as noted earlier, to overcome topographical variation and crusting. When individual furrows are supplied water as opposed to field spreading prior to the furrows, the method is called furrow irrigation.

2.4. 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, as well as information on improving design, model validation and updating, developing real time irrigation management decisions and

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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. Uniformity may be improved by adjusting the flow rate. 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.

The elements of surface irrigation system serve several functions and are generally in the following order: (1) on-off flow control, (2) conveyance, (3) water management, (4) field distribution, and (5) tail water removal or reuse.

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).

According to Bos et al. (2000), 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

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assessment should become part of the routine management procedures of the irrigation institution.

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

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 Molden et al. (1998), performance is assessed for a variety of reasons: to improve system operations, to assess progress against strategSic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess impacts of interventions, to diagnose constraints, to better understand determinants of performance, and to compare the performance of a system with others or with the same system over time. The type of performance measures chosen depends on the purpose of the performance assessment activity.

According to Yashima (1997), the following responsibilities of irrigation managers in irrigation performance assessment include (1) evaluating the existing situation of irrigation performance in their system, (2) identifying constraints to proper performance if the performance is not satisfactory, and (3) implementing management interventions to improve the performance.

2.4.1. Performance evaluation of irrigation

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).

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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, well-focused target group and its sustainability through empowerment of the beneficiaries. However, experience has shown that there are still considerable constraints and set back that hinder the introduction of small-scale irrigation.

2.4.2. Performance gaps existing in irrigation management

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

The first is a 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.

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. This can be called a gap in implementation performance. A problem of this kind generally requires changes in procedures, supervision or training.

The third kind of performance gap is the difference between management targets and actual achievements. This can be called a gap in achievement. 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.

The fourth type of performance problem concerns impacts of management. This is a difference between what people think should be the ultimate effects of irrigation and what

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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.

2.4.3. 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.

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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. Almost all operational performance indicators can, and should, be used in a spatial context whenever equity is included in the objective set.

According to Jurriens et al. (2001), the common efficiency terms used for on-farm irrigation system evaluation include application efficiency, distribution uniformity and storage efficiency. Recently complementary terms such as runoff ratio and deep percolation ration are being applied.

2.4.4. Properties of Performance Indicators

Some of the desirable attributes of performance indicators suggested by Bos (1997) are: (1) scientific basis: the indicator should be based on an empirically quantified, statistically tested causal model of that part of the irrigation process it describes. (2) Quantifiable: the data needed to quantify the indicator must be available or obtainable (measurable) with available technology. The measurement must be reproducible. (3) 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 (Bos et al. (3) 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. (4) Ease of 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, the cost of using indicators in terms of finance, equipment, and commitment of human resources, should be well within the agency’s resources.

2.4.5. 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

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methods of evaluation. The design of the irrigation scheme, the degree of lad preparation, and the skill and care of the irrigator are the principal factors influencing irrigation efficiency. Efficiency in the use of water for irrigation consists of various components and takes into account losses during storage, conveyance and application to irrigation plots. 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 in to conveyance and application efficiencies. Once the conveyance and application efficiencies have been determined, the scheme irrigation efficiency (Es) 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.

2.4.6. Conveyance efficiency

According to James (1988), the conveyance efficiency (Ec) is typically defined as the ratio between the water that reaches a farm or 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

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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.

2.4.7. Application efficiency

The field application efficiency (Ea) mainly depends on the irrigation method and the level of farmer discipline. Some indicative value of the average field application efficiency (Ea) 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.

2.4.8. Water storage efficiency

The water storage efficiency (Es) 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

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defined Es 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. Jurriens et al. (2001), express adequacy of irrigation turn in terms of storage efficiency and the purpose of an irrigation turn is to meet at least the required water depth over the entire length of the field. Conceptually, the adequacy of irrigation depends on how much water is stored within the crop root zone, losses percolating below the root zone, losses occurring as surface runoff or tail water, the uniformity of the applied water, and the remaining deficit or under-irrigation within the soil profile following irrigation.

2.4.9. Distribution uniformity

Distribution uniformity (Du) is a measure of how evenly 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.

2.5. Level of water delivery service

Two primary functions of the management of irrigation and drainage system are the supply of irrigation water and the removal of excess water to or from specific locations at specific times. The level to which these functions are to be provided has to be specified in quantitative operational service standards. These standards serve to guide the management activity, and to provide a base against which the performance of the service can be assessed.

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According to Solomon (2006), the level of service provision in irrigation and drainage is defined by Molden (2004) as: a set of operational standards set by the irrigation and drainage organization in consultation with irrigators and the government and other affected parties to manage an irrigation and drainage system. The primary task of organizational managing irrigation systems is to deliver water in accordance with a plan. In principle the formal specification of the level of service for an irrigation and drainage system emerges from a consultative process between the irrigation and drainage service provider and the water users. In some systems the level of service is clear and explicitly stated, in others it is not. The simplest, and yet probably the most important and short term, hydraulic performance indicator are those that compare actual discharge to an intended or target discharge at any given location in the system (Bos et al. 1994).

2.6. Irrigation scheduling

According to James (1988), irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper scheduling is essential for the efficient use of water, energy and other production inputs, such as fertilizer. It shows irrigations to be coordinated with other farming activities including cultivation and chemical applications. Improved crop yield and/or, quality, water and energy conservation, and lower production costs are among the benefits of proper irrigation scheduling.

FAO (1989), explained that when surface irrigation methods are used, it is not very practical to vary the irrigation depth and frequency too much. In surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all the time. Therefore, it is often sufficient to estimate the irrigation schedule and to fix the most suitable depth and interval: to keep the irrigation depth and the interval constant over the growing season.

2.7. Irrigation water requirement

2.7.1. Reference crop evapotranspiration

Several definitions of reference crop evapotranspiration (ETo) have been developed. Jansen (1993), defined ETo as the rate at which water, if available, would be removed from the soil

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and plant surface. The modified penman combination equation has been in use to compute ETo, since it is considered to be a standard method to estimate the reference crop evaportanspiration (Jensen et al. 1990).

Studies showed that the superior performance of the Penman-Montieth approach, in both arid and humid climates, and convincingly confirmed the soundness of the underlying concepts of the method. Based on these findings, the method was recommended by the FAO Panel of Experts in 1990 for adoption as a new standard for reference crop evapotaranspiration estimates (Hall, 1999). The use of the Penman-Monteith equation in irrigation practice requires empirical coefficients to modify in general to reduce but sometimes to increase the estimates of reference evapotranspiration (Stanhill, 2002).

The limited availability of the full range of climatic data (particularly data on sunshine, humidity and win speed) has often prevented the use of the combination methods and resulted in the use of empirical methods (which require only temperature, pan evaporation rate, or radiation data). This has contributed to the confusing use of different ETo methods and conflicting evapotranspiration values. To overcome this constraint and to further use a single method, additional studies has been undertaken to provide recommendations on the use of FAO Penman-Monteith method when no humidity, radiation or wind data are available. As a result, procedures are developed to estimate humidity and radiation from maximum/minimum temperature data and to adopt global estimated for wind speed.

The availability of worldwide climatic databases further facilitates the adoption of values from nearby stations. Such procedures have proven to perform better than any of the alternative empirical formulas; and will largely improve transparency of calculated evapotranspiration values.

3. MATERIAL AND METHODS

3.1. Description of the study Area

3.1.1. Location

The study was conducted at Golina irrigation scheme in the Amhara National Regional State (ANRS). It is located downstream of Aradom village which is in between Robit (01) Kebele and Kobo Town in north wollo administration zone. Golina irrigation scheme is located 10 km from Kobo Town and 40 km from Woldia town on the main asphalt road between Addis Ababa and Mekelle town. The geography located at 12° 04' 81"to 12° 08' 00" North and 39° 37' 65" to 39° 50' 62" East and has an average elevation of 1486 m.a.s.l at the weir site.

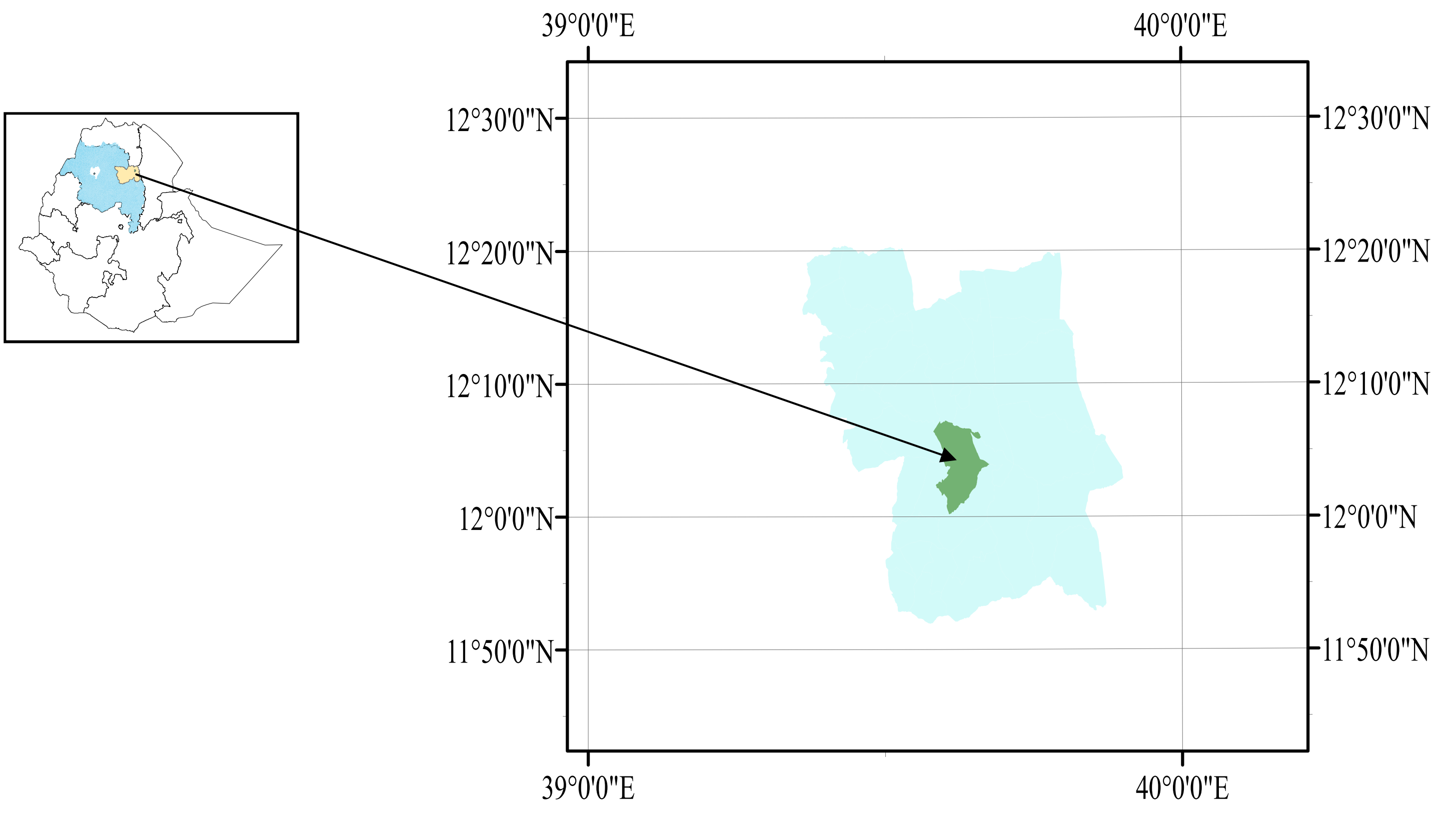

Figure 1: Location map of the study area

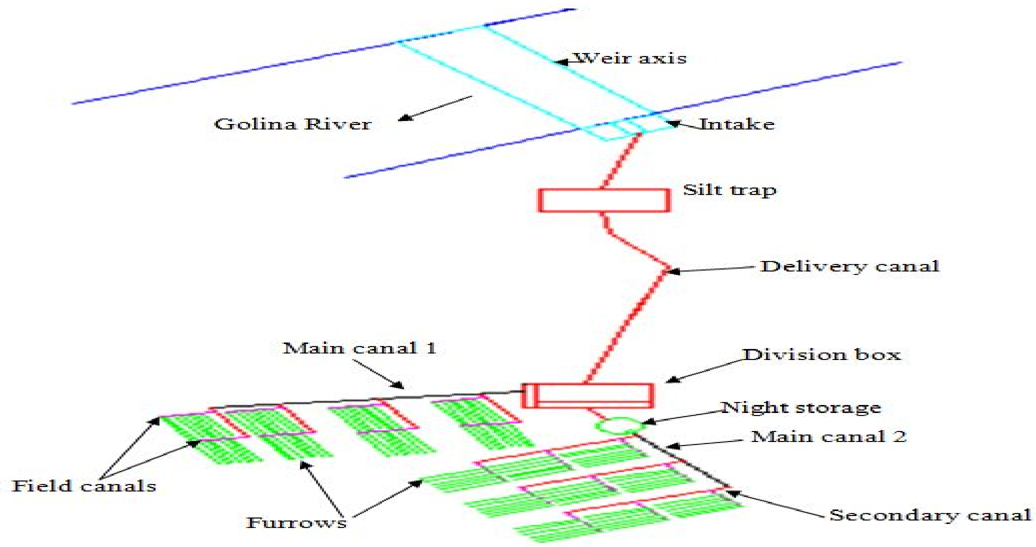

Figure 2: Golina irrigation infrastructure layout

Golina small scale irrigation project is a river diversion irrigation project studied and designed by Kobo-Alamata Agricultural Development Project and funded by Ethiopian and Italian governments and United Nations Development Program (UNDP) in 1985 (figure 2). The headwork (weir and delivery canal) (Figure 3) construction was started by Ethiopian Water Works Construction Enterprise in 1986; however, it was suspended for some years due to security problems and finally completed in 1998. Design of the infrastructure was carried out by the Ministry of Water Resource Development, and in 1998 the construction was started by a Chinese construction company and completed in 2000. The development of the irrigation scheme began in the dry season of 2001.

The Golina irrigation project command area encompasses 400 ha downstream of Aradom village on the left side of Golina River. The diversion weir is located upstream of Golina bridge (bridge constructed on the Addis–Mekelle road). The total length of the delivery canal is 1.3 km; 0.6 km lined and 0.7 km earthen. The delivery canal operates continuously for 24 hours, providing water during the day to the 1.4 km main canal #1 and during the night to the night storage reservoir, which flows to the 2.8 km main canal #2, each irrigating 200 ha.

The irrigation system also has a network of secondary and tertiary irrigation canals, drainage canals and service roads. Other structures like night storage(Appendix figure1c), road crossing structures (inverted siphons), silt traps, division boxes with gates (Figure 4) and turnouts were constructed and currently some of the structures are functional and others are not functional.

The night storage stores the night flow and the farmers use the stored water during the daytime. The night storage at its maximum level has a surface area of 2.1 ha. At this time, the night storage is still functional even though its capacity is reduced due to the inflow of sediment to the reservoir. During scheme design and construction, participation of beneficiary farmers was limited because the planning followed the top to bottom approach so often regared to by the region. At the time of completion, the irrigation infrastructures were handed over to the farmers owning plots adjacent to the nearby canals in the presence of representatives from kebele administration, woreda agriculture development office, Kobo Girana Valley Development Program (KGVDP) office and Commission for Sustainable Agriculture and Environmental Rehabilitation in Amhara Region (Co-SAERAR, 1998).

Figure 3: Golina irrigation headwork structure

Figure 4: functional division box with gates

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3.1.2. Climate

The area receives 683 mm 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. In the area, the maximum reference evapotranspiration (ETO) is 6.29 mm/day during May and June. Meteorological data such as relative humidity, sunshine hours, wind speed and rainfall from Kobo meteorological station is used to compute the crop water requirement and the intended irrigation interval. The monthly PET values at Golina are much higher than that of the monthly rainfall except in the months of July and August. This means irrigation is very indispensable in most of the months.

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.

3.1.4. Crop type

The major crops grown in Golina irrigation scheme are maize, tef, sorghum, tomato, onion and pepper. Tef 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 to determine the soil physical properties and water application or flow rate in the conveyance and field system are listed in Table 1.

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Table 1: Materials used for sample collection and analysis

Material type	Purpose
Core sampler	To collect undisturbed soil samples for soil moisture test
Auger	To take disturbed soil samples for texture analysis
Oven dry	To dry the wet soil
Measuring tape (30 m)	To Measure the dimension layout of the farm
Stopwatch or clock	To record time
Weight balance	To measure soil weight
Infiltrometer	To measure infiltration rate of soil
partial flume	To measure the rate of flowing water in the field canal and furrow

3.3. Methodology

3.3.1. Data collection methods & procedures

After the reconnaissance survey of sites where measurements to be taken, parameters to be evaluated and the indicators suitable to evaluate the performance were determined based on accessibility to the field and availability of secondary data.

In Golina irrigation scheme, three irrigation farms were selected during site observation based on soil type, slope and distance from the intake and their performance was evaluated on their suitability for the assessment. From this scheme minimum of 48 farmers were selected for interview.

To determine the amount of irrigation water applied by the farmers to the fields, partial flume (Appendix figure1f) was installed at the entrance of each field of interest 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. The total volume of water applied to the field was obtained by multiplying the discharge rate with the inflow time.

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The depth of water applied to the field was obtained by dividing the total volume of water applied to the area irrigated.

3.3.1.1. Primary data

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.

To determine soil texture, 9 samples of disturbed soil were collected from different locations in the field and it was determined in the laboratory using mechanical analysis and textural triangle.

The bulk density was measured using 9 undisturbed soil samples which were collected per each pit. Samples were collected at 30cm interval down the pit. 3 samples were collected from each interval up to the depth of 90cm. which is assumed to be the root depth for most of the crops growing in the area. The undisturbed samples were weighed and then oven dried at 105˚C for 24 hrs. The dried soil samples were re-weighed. After determining the core volume by measuring the inner diameter and height, the dry bulk density (ρ_b) was computed by dividing the oven dry weight of the sample (m_d) to known volume of core sampler(V_b) (Blake, 1965) as:

$$\rho_b = \frac{m_d}{v_b} ---------------------------------- (1)$$

The field capacity was determine in the laboratory by using a pressure plate by applying a suction of 1/3 atmosphere to a saturated soil sample. When water is no longer leaving the soil sample, the soil moisture into the sample is equal to field capacity. Permanent wilting point was also determined in the laboratory. This is the moisture content corresponding to a pressure of 15 bar atmosphere from a pressure plate test (Kirkham, 2005).

Infiltration rate:

The soil infiltration rate was determined using double ring infiltrometer of 30 cm and 60 cm diameter at three field tests. Double ring infiltrometer was installed by hammering both rings

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to a depth of 15 cm. The test started by pouring water to the depth of 70 mm. At the same time, water was added to the space between the two rings to the same depth. The water within the two rings was used to prevent a lateral spread of water from the infiltrometer. To record the water level in the inner cylinder point rod was used. The point rod was set at the desired level to which water is added. A stop watch was used to record time. After two minutes water level in the inner ring on measuring rod were recorded. The process is continued until the drop in water level is the same over the same time interval. With the same procedure extending the time at 5 minutes, 10 minutes, 20 and 30 minutes dropped water level in the inner ring on measuring rod were recorded.

Soil Moisture Content:

The soil moisture content measurements before and two days after irrigation were determined by gravimetric method which involves collecting soil samples with auger, weighing the wet soil samples, removing the water by drying in an oven at 105C^{o} and re-weighing the sample to determine the amount of water removed. Soil moisture content in each sample on weight basis in fraction (θ_w) were calculated using the equation (FAO, 1989) :

$$\theta_w = \frac{w_w - w_d}{w_d} \times 100 \text{ - } (2)$$

Where:

θ_w = Soil water content on a dry weight basis (%)

Ww = Wet weight of the soil (gm)

Wd = Dry weight of the soil [gm]

Then the moisture contents of the soils collected from the selected fields at different depths were determined.

To convert the dry weight soil moisture fraction into volumetric moisture content (θv), the dry weight fraction (θw) was multiplied by its respective bulk density (ρ_b) and divided by the specific weight of water (ρ_w) as follows;

$$\theta v = \frac{\theta_w \times \rho_b}{\rho_w} \text{ - } (3)$$

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Soil water availability:

Soil water availability refers to the capacity of soil to retain water available to plants. After heavy rainfall or irrigation, the soil will drain until it reaches to field capacity. Field capacity is the amount of water that a well-drained soil should hold against gravitational forces, or the amount of water remaining when downward drainage has markedly decreased. The total available water in the root zone was taken as the difference between the water content at field capacity and wilting point multiplied by Zr and 1000as shown below (Allen et al, 1998):

$$\text{TAW} = 1000 \times (\theta_{FC} - \theta_{wp}) \times Zr \text{ - } (4)$$

Where:

TAW = Total Available Water in the root zone [mm],

θFC = water content at field capacity [m3 m-3],

θWP = water content at wilting point [m3 m-3],

Zr = Rooting depth [m.]

TAW is the amount of water that a crop can extract from its root zone, and its magnitude depends on the type of soil and the rooting depth.

3.3.1.2. Secondary data

In addition to primary data, secondary data was collected from Kobo metrological station, Zonal Bureau of Agriculture, Zonal Bureau of Water Resources Development directive, Serinka Agricultural Research Center (SARC) and woreda agricultural office.

Secondary data included necessary reports, project documents, studies and other useful written materials. 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, cropping pattern, Climatic data and the role of irrigation water users association.

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3.3.2. Irrigation water requirement

To estimate the crop water requirements (CWR), irrigation scheduling and irrigation water requirement (IWR) of tomato, CropWat 8.0 windows computer program was used. This program uses the FAO (1992) Penman- Monteith equation for calculating reference crop evapotranspiration. The determination of the CWR by this model depends on the determination of the reference evapotranspiration values using the available climatic data. The determination of IWR will be carried out after estimation of effective rainfall by USDA soil conservation service method (Clarke, 1998).

3.3.3. Crop coefficient (Kc)

Data for crops grown in the study areas including growing stages and stage lengths (days), crop coefficients (kc), rooting depths (Zr), depletion levels (P), and yield response factors (ky) were obtained from FAO guidelines (Allen et al., 1998; Doorenbos et al., 1986).

Robert et al. (1996) about 70 percent of the root mass is found in the upper half of the maximum root depth. Under adequate moisture conditions, water uptake by the crop is about the same as the percent root distribution along the depth. Thus, about 70 percent of the water used by a crop is obtained from the upper half of the root zone. This zone is referred to as the effective root depth (Zeff). This depth should be used to compute the depth RAW. Irrigation amounts should be computed to replace only the depleted RAW within the effective root zone. Allen et al. (1998) stated that the depletion fraction (P) is a function of the evaporative power of the atmosphere and crop type. At low rates of ETc, the P values listed in Allen's et al. (1998) table are higher than at high rates of ETc and for hot dry weather conditions, where ETc is high; P is less than the values presented by Allen et al. (1998). The tabulated values for P apply for ETc ≈ 5 mm/day. The values for P will be adjusted for different ETc according to:

$$P = P_{tab} + 0.04(5 - ET_c) \text{ - } (5)$$

Where: P_{tab} is tabulated fraction (Allen et al., 1998) and ETc is in mm day^{-1}. The fraction of TAW that a crop can extract from the root zone without suffering water stress is the readily available soil water:

$$RAW = P_{adj} \times TAW \text{ - } (6)$$

Where:

RAW = Readily Available Soil Water In The Root Zone [mm]

Padj = average adjusted fraction of Total Available Soil Water (TAW) that can be depleted from the root zone before moisture stress (reduction in ET) occurs [0-1].

3.3.4. Reference crop evapotranspiration (ETo)

To calculate reference crop evapotranspiration the equation below (Allen et al. 1998) as recommended by the FAO has been in use.

$$ETo = \frac{0.408\Delta(Rn + G) + r \times \frac{900}{T + 273} u_2(e_s - e_a)}{\Delta + r(1 + 0.34u_2} \text{ - - - - - - - - - - - - - - - - - } (7)$$

Where:

ETo = Reference evapotranspiration (mm day^{-1})

Rn = Net radiation at the crop surface (MJ m^{-2} day^{-1})

G = Soil heat flux density (MJ m^{-2} day^{-1})

T = Mean daily air temperature at 2m height (^{o}C)

u_2 = Wind speed at 2m height (m s^{-1})

es = Saturation vapor pressure (kpa)

ea = actual vapor pressure (kpa)

(es-ea) = saturation vapor pressure deficit (kpa)

Δ = slope vapor pressure curve (kpa $^{o}C^{-1}$)

r = psychrometric constant (kpa $^{o}C^{-1}$)

3.3.5. Crop evapotranspiration (ETc)

To determine crop evapotranspiration ETC from reference evapotranspiration (ETo), the equation will be as follows:

$$ET_c = K_c \times ET_o \text{ - } (8)$$

Where: Kc is crop coefficient values.

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This formula represents the single crop coefficient. Crop evapotranspiration (ETc) refers to evapotranspiration of a disease-free crop, grown in very large fields, not short of water and nutrient.

The irrigation interval or frequency of irrigation was determined using the following Equation:

$$D_n = \frac{RAW}{ET_c} \text{ - (9)}$$

Where:

D_n = Irrigation interval (day)

RAW = Readily Available Water [mm]

ETc = Evapotranspiration of the crop(mm/day)

3.4. Scheme Performance Evaluation

Three farmers' field were selected, each of these was located at the head, middle and tail-end, to compare their irrigation water use efficiencies in the irrigation scheme. The four performance indices field application efficiency, conveyance efficiency, water storage efficiency and distribution uniformity were analyzed using the following equations for evaluation of scheme performance.

3.4.1. Application Efficiency (Ea)

After determining the depth of water actually applied into the fields using partial flume and the depth of the water retained in the root zone of the soil based on the soil moisture contents before and 2 days after irrigation.

$$\text{Application Efficiency(Ea)} = \frac{D_s}{D_a} \times 100 \text{ - (10)}$$

Where:

Ds =depth of water stored in the soil root zone during irrigation (mm)

Da = depth of irrigation water applied (delivered) to the farm (mm)

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The depth (Ds, mm) of water retained in the soil profile in the root zone was determined using the following equation given by Mishra and Ahmed (1990):

$$D_s = \sum_{i=0}^{n} \frac{(\theta_{AI} - \theta_{BI})}{100} i \times D_i \text{ - } (11)$$

Where:

θ_{AI} = moisture content of the ith layer of soil after irrigation on oven dry weight basis [%]

θ_{BI} = moisture content of the ith layer of soil before irrigation on oven dry weight basis [%]

Di = Depth (thickness) of ith layer (mm)

n = Number of layers in the root zone

3.4.2. Conveyance Efficiency (Ec)

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 10 m 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.

$$\text{Conveyance efficiency(Ec)} = \frac{\text{Total water supplied by the conveyance system}}{\text{Total inflow into the conveyance system}} \text{ - - - } (12)$$

3.4.3. Storage Efficiency (Es)

The water storage efficiency refers to how completely the water needed prior to the irrigation in the root zone during 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

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the plants and water needed in the root zone prior to irrigation, the storage efficiency (Es) was computed as:

$$\text{Storage efficiency(Es)} = \frac{D_s}{D_{req}} \times 100 \text{ -------------------------- } (13)$$

Where:

Ds is depth of water retained in the soil compartments of the root zone (mm) which is computed by equation 12 and Dreq is water depth required in the root zone(mm) prior to irrigation and was estimate by the following equation:

$$D_{req} = \sum_{i=0}^{n} \frac{(\theta_{FC} - \theta_{BI})}{100} i \times D_i \text{ ------------------------------- } (14)$$

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 = i_{th} layer of crop root depth (mm)

n = number of layers in the root zone

3.4.4. Distribution Uniformity (Du)

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).

$$DU = \frac{\text{Minimum depth(cm)}}{\text{Average depth(cm)}} \times 100 \text{ ---------------------------- } (15)$$

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

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have been determined, the scheme irrigation efficiency (Eo) can be calculated, using the following formula (FAO, 1989)

$$E_o = \frac{E_c \times E_a}{100} \quad (16)$$

3.6. Delivery Service

The level water delivered to the farmers' field was compared against the computed required amount of service to be given. For any irrigation system, physical and institutional factors determine the level of water that it is practical to deliver.

The performance indicators selected for this study were applied depth practiced by the farmers and management of the scheme. To determine the amount of water applied by the farmers to the fields, a Partial flume was installed at the entrance of each field of interest and readings were taken (appendix figure 9).

To evaluate irrigation water management the study area was divided into three management levels as: conveyance level, distribution level and application system. To find out the existing condition of all three level of water management, water use by crops, amount of water abstracted at different level, the amount, time and duration of water delivered to the field, soil characteristics and farmer's irrigation practices were determined.

3.7. Institutional Aspect

Using the household questionnaires interview was conducted to identify key constraints of scheme performance including planning and management, sustainability of the scheme, conflict and conflict resolution mechanisms and support services.

In order to evaluate the farmers' perception about scheme performance and institutional aspects a sample size of 48 households was chosen out of 1232 households which own irrigable land. Stratification of the scheme will be based on location relative to the canals as head, middle and tail end users

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Qualitative samples are usually small in size because if the data are properly analyzed, there will come a point where very little new evidence is obtained from each additional fieldwork unit, (Ritchie et al., 2013). According to Ritchie et al. (2013) as a very general rule of thumb, qualitative samples for a single study involving individual interviews only often lie under 50. If samples become much larger than 50 they start to become difficult to manage in terms of the quality of data collection and analysis that can be achieved. It will also take much time and budget.

3.8. Statistical Analysis

The data from close ended questionnaires was analyzed using Excel program and discussed using percentages. Information from open ended questions, key informants and informal group discussions was discussed through qualitative descriptions. Descriptive statistical measures such as mean were used for technical evaluation of the scheme.

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4. RESULTS AND DISCUSSIONS

4.1. Soil Physico-Chemical Properties of the Study Site

4.1.1. Soil texture and bulk density

As per the USDA textural classification, the soil texture was exclusively clay (Table 2). As seen in Table 3 the bulk density varied from high as 1.08 g/cm^3 to the minimum of 1.01 g/cm^3. Miller and Donahue (1995) recommended soil bulk density below 1.4 gm/cm^3 for clays and 1.6 gm/cm^3 for sands in order to get better plant growth. 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.

Table 2: Soil properties of the selected fields

Filed code	Soil depth(cm)	% Sand	% Silt	% Clay	Textural class
Head	0-30	12.04	29.92	57.97	Clay
	30-60	15.12	27.87	55.06	Clay
	60-90	17.00	26.54	56.01	Clay
Middle	0-30	13.01	30.01	58.02	Clay
	30-60	14.96	28.96	56.11	Clay
	60-90	16.21	26.20	55.22	Clay
Tail end	0-30	12.65	29.04	58.00	Clay
	30-60	16.17	28.14	57.41	Clay
	60-90	17.43	26.07	55.62	Clay

4.1.2. Soil moisture content at FC and PWP

The soil moisture content at field capacity varied from 0.323m^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 0.212m^3/m^3 to the maximum value of 0.239m^3/m^3 on volume basis (Table 3). The total available soil moisture varies from the lower value of 102.50mm/m to higher value of 162.80mm/m. The value of FC, PWP and TAW were found to be in the range given by FAO (1998)(Appendix Table 12).

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Table 3: Soil moisture (FC, PWP, TAW) and bulk density

$\theta_{fc}(m^3/m^3)$	θ_{wp} (m^3/m^3)	Bulk density	TAW(mm/m)	TAW(mm)	RAW(mm)
0.400	0.239	1.070	160.90	144.810	56.476
0.399	0.236	1.030	162.80	146.520	57.143
0.393	0.233	1.010	159.90	143.910	56.125
0.397	0.236	1.090	160.90	144.810	56.476
0.388	0.235	1.060	153.20	137.880	53.773
0.376	0.234	1.020	142.10	127.890	49.877
0.338	0.236	1.080	102.50	92.250	35.978
0.336	0.228	1.050	108.90	98.010	38.224
0.323	0.212	1.020	111.00	99.900	38.961

4.1.2. Soil infiltration rate

To determine the infiltration characteristics of the soil, the infiltration rate was measured at three test plots (head, middle and tail) using double ring infiltrometer. It is found that the average basic infiltration rate was found to be 7.2 mm/hr, 6.0 mm/hr and 5.2 mm/hr at head, middle and tail end of test plot, respectively. The average basic infiltration rate of the scheme measured was 6.13 mm/hr. According to Kay (1986) the basic infiltration rate of a soil is in the range 1-10 mm/hr, it is classified as a soil with low infiltration rate which is the typical characteristics of clay textured soil. Hence the result of textural classification and infiltration rate are in good agreement. AppendixTable13, 14 and 15 shows infiltrometer data taken from head, middle and tail end plots respectively.

4.2. Performance Evaluation of the Scheme

4.2.2. Conveyance Efficiency

While evaluating the performance of an irrigation scheme, one of the components with poor performance which become noticeable quickly is the 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

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was computed using equation (12) considering the total flow delivered by conveyance system and total inflow into the system (Table 4). During the study period, average conveyance efficiency of the main canal one from main intake up to the tail end and main canal two from intake 2 up to the tail end determined from the discharge measurements using area-velocity method was 84.65% and 83.56% respectively.

Table 4: Main canal one and two conveyance efficiency

System	Mean discharge inflow(l/s)	Mean outflow (l/s)	Ec(%)
Main intake(intake1)-Mc1 head (lined)	343	328	95.6
Mc1 head- Mc1 lower(unlined)	328	241.7	73.7
Intak2 – mc 2 head	285	211.2	74
MC2 head – MC2 middle	211.2	172	81
MC2 middle-MC2 end	172	144	83.7

As can be seen from the above Table 4, the conveyance efficiency of the main canal one was 73.7%. The amount of water lost in 1400m length of main canal one was 86.3 l/s or 7456.3 m3 per day. This showed that 26.3 % loss of water was occurring in the main canal one.

The conveyance efficiency of the main canal two head, middle and tail end was 74%, 81% and 83.7% respectively. The corresponding amount of water lost in 933m, 934m and 933m length of main canal two was 73.8 l/s, 39.2 l/s and 28 l/s or 6376.3 m3 per day, 3386.9 m3 per day and 2419.2 m3 per day respectively. The respective percentage loss of water was 25.9%, 18.6% and 16.3 %.

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 found to be out of the acceptable range. Therefore, large amount of water was lost. The reasons for losses in both main canals is mainly related to spillage/ seepage losses, unauthorized diversion of water by farmers into field ditches and overtopping of the water from the canal (appendix figure1b). Conveyance losses refer to the fraction that is lost when irrigation water travels from its source to the field through the

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conveyance network, including losses due to seepage, leakage and overtopping (Van Halsema et al. 2011).

Table 5: secondary canals conveyance efficiency

System	Mean discharge inflow(l/s)	Mean outflow(l/s)	Ec(%)
SC1 head- SC1 lower	225	128	57
SC2 head- SC2 lower	209.3	165.6	79
SC3 head –SC3 lower	200	160	80
SC4 head- SC4 lower	191	150.5	78.8
SC5 head- SC5 lower	168.7	96.8	57.4
SC6 head- SC6 lower	166.5	120	72

The conveyance efficiency of the secondary canal1 and 5 is 57% and 57.4% respectively. The corresponding discharge lost was estimated as97 l/s and 72 l/s or 8381 m^3 per day and 6212.2m^3 per day respectively. The efficiency of secondary canal1 and 5 is found below standard (Walker 1989) 60 percent and (Brower and Heibloem 2011) minimum 75 percent. The reason for this loss is due to seepage and spillage occurred in the secondary canal section as observed in the field. Secondary canal 2, 3, 4 and 6 have efficiency of 79%, 80%, 78.8% and 72% respectively. These figures can be considered as acceptable in terms of percentage. However, in reality, the corresponding amount of water lost from these secondary canals is 3776, 3456, 3499 and 4018 m^3 per day respectively. This is significant amount of water that could have been used for additional irrigation in the study area. On the other hand, this loss would have been avoidable with canal lining or minimized with proper maintenance like compaction with clay and other selected materials.

4.2.3. Water application efficiency

Table 6 presents summery of the results of application efficiency (Ea) obtained using the method described in equation (10) for head, middle and tail reaches.

The estimated application efficiency values were 48.26%, 68.52% and 75.65% at head, middle and tail reaches respectively. This indicates that the head end users are inefficient since apply

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the excess water to their fields. Further, looking in to the depth of water applied (Table 6) more water was applied by head end test plot (348.33mm) than tail end test plot (205.40mm). This could rise from the expectation of the farmer that more water means more production. The application efficiency was, 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 got.

The average values 0f 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 50-60%. Roger.et.al, 1997 and US (SCS) reported the maximum attainable application efficiency as in range of 50-90% and 55-70% respectively.

Table 6: Determinations of efficiencies of the selected plots

Filed code	Applied depth(mm)	Stored depth Ds(mm)	Ea (%)	Stored depth Ds(mm)	Dreq	Es (%)	DU (%)
u/s plot	348.33	168.09	48.26	168.09	189.58	88.66	74.48
middle plot	214.86	147.21	68.51	147.21	157.78	93.30	73.73
tail plot	205.40	155.39	75.65	155.39	159.70	97.30	86.95

4.2.4. 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 (13) indicate that the storage efficiency of these fields can be regarded as high.

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Storage efficiency of the head, middle and tail end plots were 88.66%, 93.30% and 97.30% respectively (Table 6), with mean value of 93.10%.

According to Raghuwanshi and Wallender (1998), the recommended storage efficiency is 87.5%. Thus, the storage efficiency of the scheme indicated that the irrigation system was sufficient in fulfilling the soil moisture required for good productivity of the crops.

4.2.5. Distribution Uniformity

The distribution uniformities of the scheme were found to be 74.48%, 73.73% and 86.95% in the head, middle and tail end fields, respectively (Table 6), with the average value of 78.4%. 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 (78.4%) of the scheme indicated the distribution uniformity of irrigation water in the selected farmers' field was sufficient.

4.2.6. Overall irrigation efficiency

The overall efficiency of the scheme was found to be 48% (equation 17). 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. Hence, the overall efficiency of the scheme indicated the efficiency of the scheme is poor.

4.3. Impact of the delivery system

The scheme was designed to deliver irrigation water to individual fields based on proportional flows throughout the irrigation season, but actual water delivery service to irrigators was unknown date and volume since no water measuring equipment was found in the scheme. Irrigation water delivered from intakes to main canals were operated by "Yewuha Abats" and after completing canal cleaning the gate is opened until the end of the season, but the flow rate is not as intended.

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Table 7: Depth of water applied to the field and released from the main canal

Field location	depth applied in one irrigation event(mm)	depth of water released from mc (mm)	delivery service in %
Head	348.33	586.3	59.41
Middle	214.86	343	62.64
End	205.40	277.7	73.96

Moreover, from the total depth of water released in one irrigation event through the main canal at head, middle and tail reaches, 59.41%, 62.64% and 73.96% reached the selected farmers' fields which are located in their respective section, respectively (Table 7). These values indicated that a considerable amount of water which was released from the main canal was lost by seepage and overtopping. Thus, the water delivery system of the main canal 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.

The intended service being delivered by "Yewuha Abats" to its users can be quantified through the delivery service level. In Golina irrigation scheme the delivery service level is not clearly stated. However, it is known by each user that "Yewuha Abats" will provide water to users based on the water existing in canal system.

Therefore, comparison of the water delivered to the farmers throughout the irrigation period and the actual amount of IWR is shown in Table 8.

Table 8: applied depth of water by farmers

Field location	depth applied in one irrigation event(mm)	Irrigation requirement (mm)
Head	348.33	617.9
Middle	214.86	617.9
End	205.40	617.9

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As shown in Table 8, depth of water applied during one irrigation event to the selected farmers' field located at the head, middle and tail-end equals to 348.33 mm, 214.86 mm and 205.40 mm, respectively. However, the calculated IWR using CropWat 8.0 at the scheme was 617.9 mm/season. This implied that the amount of water applied to the fields during one irrigation event was too much. Therefore, the delivery service delivered to the farmers was poor resulting wastage of scarce resource.

The deviation between the actual depth applied by the farmers and actual amount to be delivered was used as a measure of the magnitude of failure in the delivery system. Therefore, the results indicated that delivery of irrigation water during irrigation period was poor.

A manageable supply is one that enables constant flow rate once adjusted, adjustable flow rate, the correct flow rate to match their soil and field size, and ability to receive water when it is needed (frequency) and shut off when they have completed the irrigation (duration) event. As mentioned earlier, actual water delivery service to irrigators was doubtful rotation, unknown date and volume since no water measuring equipment found in the scheme. Thus, the supply of the scheme was considered as not manageable.

4.4. Institutional Aspect

To assess farmers' perception about scheme performance, evaluation was made at the project site by interviewing 48 households with structured questionnaire. The questionnaire stressed on the planning, management and sustainability of the project. Respondents were selected randomly from 1232 households' heads in the scheme. From all respondents 38.2% were illiterate, 20.8% were primary education completed and 41% were read and write only. All respondents were scheme beneficiaries.

4.4.2. Organization and Management

The Water Users Association was established in 2002 with 22 male and 5 female members. Currently, the members of the cooperative reached 270 out of which 13 are females. There are 1232 potential beneficiary members in the scheme. However, about 80% of the beneficiaries

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have not yet become members of the association. Irrigation users had not become members of the association because of a lack of awareness of the association and its functions.

The association was organized in such a way that there are "Wuha Abats" based on primary and secondary canals. The farmers laid in one primary and secondary canal would have one "Wuha Abat" (leader) who is responsible for managing his/her member. Therefore, the numbers of "Wuha Abats" are depending up on the number of primary and secondary canals (one "Wuha Abat" per primary or secondary canal). "Wuha Abats" are accountable for the chairman of the association. The association has its own leadership (chairman, secretary, treasure) and by-laws to which they stick in the course of the development.

The objective of WUA is for greater user commitment, which can lead to more efficient use of the resources by helping to overcome many of the problems that public irrigation systems face, such as inequitable water distribution, corruption, inefficiency and poor operation and maintenance. Attention is nowadays being focused on how to achieve this commitment, and to what extent WUAs can be assisted to form and to manage their own affairs (FAO, 1996).

Payment of annual water fee from all water users is the main source of income for the association. Each beneficiary is expected to pay an annual water use fee. Currently, users pay 20 birr/ha for water use.

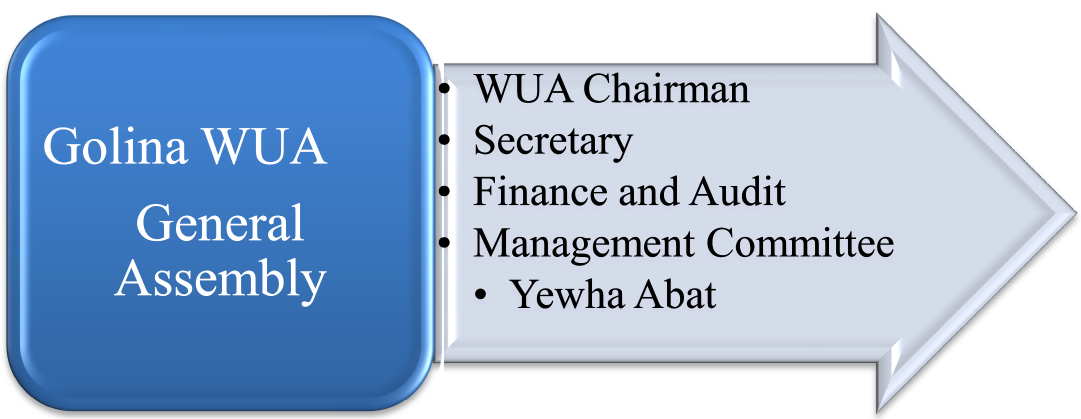

Figure 5: Scheme organization chart

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4.4.3. Conflict and Conflict Resolution Mechanisms

Among the selected respondents 75% confirmed that there is conflict on the use of irrigation water (Table 9).

As it is indicated in Table 10, 27.1% of the respondents said maintenance is their prior problem that makes the scheme to be inefficient. Next to this, 20.8%, 18.7% and 12.5% of the respondents agree on their problem to be water theft or unauthorized canal breaching in the scheme, water shortage and water utilization conflict respectively. According to the informants, there is conflict among users especially, in the months of April and May. In July when the onset of monsoon is delayed farmers also need irrigation water to crops like tomato or onion which normally grow rain fed. This problem is further compounded by the significant decrease of the river water discharge. Since that time no serious conflict is observed.

Table 9: response of households on conflict

Is there any conflict on the use of irrigation water	Frequency	Percent (%)
Yes	36	75
No	12	25
Total	48	100

Table 10: Major problems that make the scheme inefficient

Problems	Frequency	Percent (%)
Water shortage	9	18.7
Maintenance problem	13	27.1
Market problem	3	6.25
Labor shortage	2	4.2
Input shortage	5	10.4
Water utilization conflict	6	12.5
Water theft	10	20.8
Total	48	100.00

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All respondents confirmed that the communities have a system of rule for controlling the conflict within the scheme. There is bylaw, currently enforced in the scheme. According to their bylaw, the main duties of the water users committee include coordinating the timely cleaning of canals, facilitating water distribution and conflict resolution. Currently, the committee is mainly involved in the coordination of canal cleaning and water distribution.

4.4.4. Training and support service

Farmers were asked if they were given training on irrigation water management or not. In the scheme 75% responded that no such training has been given before. On the other hand, 25% of them reported that they are being given training in the areas of irrigation agronomy, on farm water management and crop diversification (Table 11). The training, they said, was offered by Kobo Girana Valley Development Program (KGVDP), Sirinka agricultural research center and the Wereda Agriculture and Cooperative Offices. But most of the trainees were members of the WUA.

Table 11: Training on irrigation water management

Given training	Frequency	Percent (%)
Yes	12	25
No	36	75
Total	48	100

4.4.5. Sustainability of the Scheme

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 investment in irrigation scheme design and construction without participation of the community in the area. This leads to dependency on the government which decreases farmers' sense of ownership and responsibility for operation and management.

Participation is the active involvement of development beneficiaries in the choice, implementation and management of development projects that are designed to improve their standards of living. The pre-conditions for effective community participation are that the

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community members must understand the problems they experience and conceptualize the desirable actions to address the problem. The level of participation is discernible from the farmer's willingness to contribute to the project activities in terms of commitment of time, labor and material resources. According to the respondents only 37.5% of the respondents participate in the scheme development through labor contribution and the rest 62.5% of the respondents said they do not have any contribution either in money or labor (Table 13).

All respondents confirmed that the irrigation scheme is very important for them to secure food self-sufficiency. This leads to the conclusion that community had awareness about advantages of irrigation agriculture. The idea of constructing the irrigation scheme on the site was originally initiated by the government but later agreement was reached between the government and the local community.

Table 12: ownership level of beneficiary households

Have you ever participated in maintenance of irrigation scheme?	Frequency	Percent (%)
Yes	6	12.5
No	42	87.5
Total	48	100

Table 13: participation in development of the scheme

What is your contribution in the scheme development?	Frequency	Percent (%)
Labor contribution	18	37.5
No contribution either in money or labor	30	62.5
Total	48	100

4.4.6. Water management

The water distribution is decided by the beneficiaries themselves with no predetermined schedule (without specifying the date and queuing order of each beneficiary). 75% of the respondent confirmed that water supply to each farmer is decided by themselves and is fixed on daily basis than hours based on their irrigation schedule (Table 14). The household with the

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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 24 hrs. This showed that the WUA 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 14: decision on irrigation schedule

Who decides on how much and when to irrigate`	Frequency	Percent (%)
Kebele administration	0	0
WUA	12	25
Beneficiary households	36	75
Total	48	100

The system operates starting from late December or early January to end of June unless there is rain. 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 15: response of households on the criteria to decide when to irrigate

What criteria do you use to decide when to irrigate	Frequency	Percent (%)
Wait until the crop leaves wilt	6	12.5
Check the soil near the roots	27	56.25
When it is dry	15	31.25
Irrigate every day	0	0
Total	48	100

31.25% of the respondents replied that they irrigate their crop when the soil near the crop roots is dry; and 12.5% of the respondents replied that they will wait until the crops leaves wilt.

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4.4.7. Food insecurity

Most of the respondent households (68.4%) produce enough food grains that cover the consumption demand for the whole year. But the remaining 24.4% and 6.2% of the respondents produce cover the first six months beginning from rain fed crop harvest (Nov-April) and less than six months respectively. The food consumption during remaining six months of the year will be covered by purchasing cereals from nearby markets. The income to buy the grains is obtained by borrowing money from Amhara credit and saving institution (ACSI) (29.2%) and involving in nonfarm activities (6.25%), sale of vegetables produced under irrigation (60.42%), and animal sales (4.2%). This indicates that how irrigation is important venture to accomplish food security (Table 16).

Table 16: solution for food shortage

Solution for food shortage	Frequency	Percent (%)
Sale of vegetables produced in irrigation	29	60.42
Borrow money	14	29.2
Nonfarm activity	3	6.25
Animal sales	2	4.2
Total	48	100

4.4.8. Market

There are three main market centers for the community. These are Kobo, Robit and Aradom towns which are 10 and 8 km far from Aradom kebele. Most of the time farmers sell their outputs to private traders at sit. The irrigation cooperative has limited financial and business capacity to assemble and market farmers' produces. The perish ability and bulkiness nature of the farm products forced farmers to sell their products with the price determined by the buyer. Farmers do not have chance to deal with the price. Accordingly, the net return they get from irrigation becomes low and discourages farmers and cut down their contribution and effort to make the scheme more efficient.

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5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. SUMMARY

The principal objective of surface irrigation systems evaluation is to identify management practices and system configurations that is feasibly and effective to improve irrigation efficiency. Evaluation plays a fundamental role in improving surface irrigation systems by providing the information required for design, model validation, and advising irrigators on how to improve their systems and management practices.

This study was made in an attempt to address the performance of Golina irrigation scheme. Attempts have been made to characterize the scheme, evaluate its application and distribution uniformity, and scrutinize water equity related problems.

Primary field data collected include canals and canal structures physical parameters, investigation of water application methods and practices, management techniques used by farmers on their fields; measurement of water flow in the canals at different locations to determine conveyance efficiencies, water level at the head of the scheme diversion and measurement of the amount of water applied to the selected fields and the determination of soil moisture contents of the soils of the selected irrigation fields before and two days after irrigation by taking soil samples at different depths.

The main canal-1 conveyance efficiencies investigated on1400 m length canal reaches using floating method were 73.7% and the average main canal-2 conveyance efficiencies investigated on 933 m length canal reaches using floating method were 79.57%. This showed that 26.3 % loss of water occurred in the main canal-1 and 25.9%, 18.6% and 16.3% loss of water occurred in head, middle and tail end of main canal-2. It was found to be out of the acceptable range and large amount of water was lost. The reasons for losses in both main canals is mainly related to spillage/ seepage losses, unauthorized diversion of water by farmers into field ditches and overtopping of the water from the canal. The corresponding rate of conveyances losses were 0.06 and 0.05 l/s per meter length of canal for main canal-1 and main canal-2 respectively.

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Field efficiencies of three fields located at head, middle and tail reach of the scheme were evaluated by measurement using partial flume. The study showed that the average application efficiencies of upstream, middle and down-stream fields were 48.26%, 68.51% and 75.65%, respectively.

Application efficiency is mainly related to the management of water at field level, and the result indicate that the tail reach irrigators were the most efficient in applying water to their fields as compared to the middle and head irrigators. The head irrigator was the least efficient.

Storage efficiency, Es of the scheme varies between 88.66% and 97.30% with mean value of 93%. This value indicated that the irrigation system was adequate in fulfilling the soil moisture required for good productivity of the crops. Regarding application uniformity, average DU of the selected fields was 78.4%.

The scheme was designed to deliver irrigation water to individual fields based on proportional flows throughout the irrigation season, but actual water delivery service to irrigators was uncertain rotation, unknown date and volume since no water measuring equipment found in the scheme.

In Golina irrigation scheme the delivery service is not clearly stated. However, it is known by each user that “Yewuha Abats” will provide water to users based on the water existing in canal system. Therefore, the study focuses on comparing the delivery service delivered to the farmers’ throughout the irrigation period and the actual amount of IWR which was calculated by CropWat 8.0 computer model.

Questionnaire-based interviews were administered to identify key constraints of scheme performance including (participation and sense of ownership of the scheme, major problems decreasing the efficiency of the scheme).

The study revealed that the level of participation is discernible from the farmer’s willingness to contribute to the project activities in terms of commitment of time, labor and material resources. According to the respondents only 37.5% of the respondents participate in the scheme development through labor contribution and the rest 62.5% of the respondents said they do not have any contribution either in money or labor. Based on major problems 27.1% of the respondents said maintenance problem is their priority problem that makes the scheme

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to be inefficient. Next to this, 20.8%, 18.7% and 12.5% of the respondents agree on their problem to be water theft or unauthorized canal breaching in the scheme, water shortage and water utilization conflict respectively.

5.2. CONCLUSIONS

From this research the following conclusions can be outlined.

The conveyance efficiencies of the main canals and secondary canals were found to be below the recommended value and large amount of water was lost. The reasons for losses in both main canals and secondary canals are mainly related to spillage/ seepage losses, unauthorized diversion of water by farmers into field ditches and overtopping of the water from the canal. There was plenty of evidence that canals were poorly maintained, with frequent canal breaching including from the main canal.

The irrigation water application at farmers' field level in the scheme at the head location was poor. Low efficiencies were achieved because excess water was used by farmers. This was due to the fact that the system permitted farmers to apply large volume of water to their fields combined with poor knowledge about the crop water requirements of the farmer.

The storage efficiency of the scheme indicated that the irrigation system was sufficient in fulfilling the soil moisture required for good productivity of the crops. Regarding distribution uniformity, the distribution uniformity of irrigation water in the selected farmers' field was sufficient. The possible reason can be suitability of slope of the command area which is nearly flat.

Based on delivery service, from the total depth of water released in one irrigation event through the main canal at head, middle and tail end plots a considerable amount of water was lost by seepage and overtopping. The water delivery system of main canal of tail end users was more efficient than middle and head end users. The middle user was more efficient than the head end user.

Depth of water applied during one irrigation event to the selected farmers' field located at the head, middle and tail-end plots exceeds the IWR of the scheme. This implied that the amount of water applied to the fields during one irrigation event was too much. Therefore, the delivery

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service delivered to the farmers was poor resulting wastage of scarce resource. According to management, actual water delivery service to irrigators was unknown date and volume since no water measuring equipment found in the scheme. Thus, the supply of the scheme was considered as not manageable.

Although Water User Association is established, it was not well strengthened to handle the water management responsibility as result individual beneficiaries are operating the system. As a result conflict among users due to water theft and unauthorized canal breaking observed.

Although beneficiary farmers have initiated the irrigation project, they were not participated during construction. Good performance of scheme is directly related to the level of involvement of community members in the planning as well as implementation phase. If this does not met, beneficiaries does not develop sense of ownership and sustainability of the scheme would be in question.

In the irrigation project, there are social, legal, technical, and institutional problems adversely affecting the performance system. The institutional structure of the irrigation scheme needs to be strengthened further.

5.3. RECOMMENDATIONS

From the conclusion reached, the following recommendations are drawn:

- The primary and secondary canals should be lined and all non functional infrastructures like division boxes, drop structures and turnouts needs to be reconstructed; and during construction, the excavated earth shall be well compacted with selected material to avoid settlement and collapse of structures.
- The on-farm water application should be improved by preparing common farm plans that can be the basis for preparing common irrigation schedules for groups of farmers, thus improving the reliability of water supply. This prevents conflict among users due to water theft and unauthorized canal breaking.
- Regular training on over all irrigation water management, Irrigation agronomy, scheme operation and maintenance should be given to beneficiary farmers.

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- Assigning irrigation agronomist and technician to the scheme and conducting on-job training to them may have a paramount contribution to the improvement of the scheme Performance.

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

- Empowerment of the WUA is fundamental for irrigation scheme sustainability. Hence, WUA of Golina irrigation scheme has to be further strengthened and by-law should be put practical. Effort should also be made to bring all beneficiaries of the irrigation scheme under one WUA so that all shall observe the bylaws of the WUA.

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7. APPENDICES

7.1. APPENDIX TABLES

Appendix Table 1: Computed conveyance efficiency of the main canals and secondary canals for Golina irrigation scheme

Canal section	Avg depth(m)	Avg width(m)	Area (m2)	Length (m)	Avg time elapsed(sec)	Velocity (m/s)	Discharge (m3/s)	Ec(%)
UMC1	0.5863	1	0.5863	10	17.81	0.56	0.3283	
LMC1	0.4	1.425	0.57	10	23.57	0.424	0.242	73.7
UMC2	0.343	1.405	0.48	10	22.8	0.44	0.2112	
MMC2	0.2777	1.375	0.382	10	22.38	0.45	0.172	81
LMC2	0.248	1.2	0.3	10	20.92	0.48	0.144	83.7
USC1	0.55	0.93	0.5115	10	22.53	0.44	0.225	
LSC1	0.4	0.735	0.294	10	23.03	0.434	0.128	57
USC2	0.5617	0.81	0.455	10	21.7	0.46	0.2093	
LSC2	0.5	0.725	0.36	10	21.72	0.46	0.1656	79
USC3	0.544	0.815	0.44	10	23.03	0.434	0.191	
LSC3	0.536	0.66	0.35	10	23.4	0.43	0.1505	78.8
USC4	0.5357	0.82	0.44	10	22	0.4545	0.2	
LSC4	0.505	0.65	0.33	10	20.58	0.486	0.16	80
USC5	0.529	0.7	0.37	10	21.93	0.456	0.1687	
LSC5	0.511	0.43	0.22	10	22.75	0.44	0.0968	57.4
USC6	0.533	0.7	0.37	10	22.25	0.45	0.1665	
LSC6	0.5	0.6	0.3	10	24.71	0.4	0.12	72

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Appendix Table 2: Soil moisture content before and two days after irrigation at 90 cm depth

crop stage	Time of Sampling	Field locations in the scheme								
		U/S			M/S			D/S		
		0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Initial stage	Before Irrigation	13.91	16.95	18.30	10.66	16.42	18.49	15.29	17.27	18.69
	After Irrigation	23.80	33.08	37.81	28.05	31.60	36.30	31.36	35.99	38.31
Dev. Stage	Before irrigation	15.68	19.34	21.53	14.70	20.20	23.27	12.21	14.41	16.00
	After irrigation	29.10	37.98	44.44	33.63	36.22	40.37	27.42	32.55	34.74
mid stage	Before Irrigation	19.28	22.29	24.10	20.46	25.69	29.20	10.70	12.80	14.08
	After Irrigation	38.04	43.27	50.90	37.30	40.22	45.58	24.81	29.41	32.53

Dev. Is development, U/S is upstream, M/S is middle stream and D/S is downstream fields

Appendix Table 3: Irrigation water measurement result

Filed code	area(m2)	T(sec)	Q(l/s)	total volume (lit)	Total volume (m3)	applied depth(m)	applied depth(mm)	stored depth(mm)
u/s plot	300	22000	4.75	104500	104.50	0.348	348.33	168.09
middle plot	350	18800	4.00	75200	75.20	0.215	214.86	147.21
tail plot	400	21068	3.80	82165	82.165	0.205	205.41	155.39

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Appendix Table 4: application efficiency, storage efficiency and distribution uniformity

Plots	Applied depth(mm)	Stored depth Ds(mm)	Ea(%)	Stored depth Ds(mm)	Dreq	Es(%)	DU(%)
u/s plot	343.33	168.09	48.26	168.09	189.58	88.66	74.48
middle plot	214.86	147.21	68.51	147.21	157.78	93.30	73.73
tail plot	205.4	155.39	75.65	155.39	159.70	97.30	86.95

Appendix Table **5**: Monthly rainfall (mm) data at Kobo meteorology station

Year	Jan	Feb	march	April	May	jun	Jul	Aug	sep	Oct	Nov	Dec
2006	0	10.8	56.7	62.6	15.9	3	81.2	222.9	75.4	12.5	0	16.6
2007	17.8	11.8	36.9	46.6	7.7	29	200	220.7	194.3	0	0	0
2008	13.3	0	0	8.4	16.2	21.2	125.7	211	139.3	6.3	31.9	0
2009	6.4	0	6.7	31.9	0.6	1.4	159.2	126.1	9.9	51.6	22.1	50.8
2010	0	10.5	4.3	65.1	72.3	1.8	245.4	310.5	45.9	14.7	0	0.5
2011	0.6	0	18.9	30.2	79.5	0	69	176	10.8	13.4	26.1	0
2012	0	0	47.7	35.8	19.2	43.5	53.5	291.8	43	12	0	4
2013	18.8	1	26.2	57.5	4.9	4	179.8	176.9	44	30.4	5.7	0
2014	0	10.7	59.4	31.7	153.4	4.5	154.2	255.8	190.1	85.9	22.8	3.8
2015	0	0	19.1	0	63.9	4.2	20.5	156.1	60.5	0	0	64.1
Ave	5.69	4.48	27.59	36.98	43.36	11.26	128.85	214.78	81.32	22.68	10.86	13.98

Appendix Table 6: Minimum Temperature at Kobo meteorology station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	1.8	2.4	7.4	9.2	11.2	12	11.2	15.8	13.2	11	7.2	7.8
2002	9	9.2	14.4	11.5	13	16	16.5	16	13	11	10	11.5
2003	6	12	12	13	15	16.5	16.5	15.5	14.8	8.2	9.4	6
2004	10	10.4	7	13.8	14.4	14.6	15.4	15	13.4	9	9.9	5.6
2005	6.4	9.2	13.2	15.2	13.6	15	15.4	15.4	14	11.2	8.2	7
2006	9	9	10	12.2	16	16	16.2	15.2	14	10.2	10.4	9.4
2007	10.4	13	9	7.8	8	15.4	13	15.4	11.2	8.6	6.4	7
2008	6	8	8.2	11	15.4	15	15.4	15.4	13.6	10.2	7.4	7.2
2009	8	11.2	13.2	14.4	15.4	17.4	15.2	16.4	13.4	11.2	9.8	11.6
2010	10	11.2	10.2	15.4	14.8	16.6	15	15.1	12.4	11.4	8.2	6.2
2011	9.4	10	10.8	11.6	14	15	15	14.8	13	9.2	9.4	5.4
2012	5.2	8	8.1	15	13.8	15	15.4	15	13.2	9.8	9	9.2
2013	9.8	10.2	13.4	16	17	11.8	15.4	15.4	14	11	9.2	8.6
Mean	7.8	9.5	10.5	12.8	14.0	15.1	15.0	15.4	13.3	10.2	8.8	7.9

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Appendix Table 7: Maximum Temperature at Kobo meteorology station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	27.1	30.2	31.2	34.6	33.8	36.4	35.4	32.6	32.1	32	31.8	30
2002	28.2	32.2	34	34.5	36.4	37	37	33	32	32	31	30
2003	31	33	33	33.4	36	37	35	33	33	31.4	31.6	30.8
2004	31.4	31.2	32.2	33.6	36.4	38.2	37	33.8	34	31.6	31.2	29
2005	30.6	33.8	33.6	35.2	34.2	36.8	36	34.2	34	32	32	30.2
2006	31.2	32.2	34.6	34	35.8	37.6	36.4	34.4	32.6	32.6	30	29.4
2007	27.6	32.2	34.4	33.6	36.4	36.4	31.8	32.8	32.4	30.8	29	29.8
2008	30.4	31	33.4	34.6	35.4	34.5	32	31.5	30.7	28.1	26.9	26.8
2009	29	31.6	34.4	34.8	36.2	37	37	33.8	33.4	33	31.2	31
2010	28.8	31.6	32.8	34	34.8	38	36.4	31.2	31.5	31.6	30	29
2011	30.4	31.6	31.8	33.6	34	37.2	35.4	32	33.4	31.6	29.6	29.8
2012	30	33	32	32.2	35.2	36.8	36	31.4	32.4	31.5	30.2	29.4
2013	33.2	32.8	33.6	33.4	36	37.4	36	32	32.4	32	30.2	30
2014	30	31	33	34	34	35.8	36.6	33	32.5	31.4	30.5	30.3
2015	30	31.6	26.6	34.1	36.5	36.4	36.8	36.4	36.4	36.6	36.6	35.8
Mean	29.9	31.9	32.7	34.0	35.4	36.8	35.7	33.0	32.9	31.9	30.8	30.1

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Appendix Table 8: ETO

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	Eto mm/day
January	7.8	29.9	56	173	7.5	18	4.35
February	9.5	31.9	51	193	9.2	21.8	5.38
March	10.5	32.7	49	203	8.4	22	5.78
April	12.8	34	48	202	8.4	22.5	6.1
May	14	35.4	41	183	9.1	23.2	6.36
June	15.1	36.8	32	203	8.3	21.7	6.82
July	15	35.7	49	192	6.3	18.8	5.79
August	15.4	33	59	138	6.3	19	4.86
September	13.3	32.9	57	100	6.3	18.9	4.52
October	10.2	31.9	49	116	9.1	22	4.91
November	8.8	30.8	48	142	8.6	19.7	4.6
December	7.9	30.1	52	141	8.4	18.7	4.25
Average	11.7	32.9	49	166	8	20.5	5.31

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Appendix Table 9: Effective rain fall (mm)

	Jan	Febr	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Rain mm	5.7	4.5	27.6	37	43.4	11.3	128.9	214.8	81.3	22.7	10.9	14	602
Eff rain mm	5.6	4.5	26.4	34.8	40.4	11.1	102.3	141	70.7	21.9	10.7	13.7	483

Appendix Table 10: Crop water requirement (CWR)

Month	Decade	Stage	Kc	ETc mm/day	ETc Dec	Eff rain Dec	Irr.Req. mm/Dec
Jan	2	Init	0.6	2.55	7.6	0.5	7.6
Jan	3	Init	0.6	2.78	30.5	1.6	29
Feb	1	Init	0.6	3.02	30.2	0.9	29.3
Feb	2	Deve	0.61	3.3	33	0.4	32.6
Feb	3	Deve	0.72	3.95	31.6	3.2	28.4
Mar	1	Deve	0.84	4.75	47.5	6.8	40.7
Mar	2	Deve	0.98	5.66	56.6	9.4	47.2
Mar	3	Mid	1.11	6.56	72.2	10.1	62.1
Apr	1	Mid	1.15	6.89	68.9	10.7	58.2
Apr	2	Mid	1.15	7.01	70.1	11.7	58.4
Apr	3	Mid	1.15	7.11	71.1	12.3	58.8
May	1	Late	1.14	7.16	71.6	13.9	57.7
May	2	Late	1.03	6.56	65.6	15.1	50.5
May	3	Late	0.88	5.76	63.3	11.3	52.1
Jun	1	Late	0.8	5.39	5.4	0.3	5.4
Total					725.3	108.2	617.9

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Appendix Table 11: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
22-Jan	5	Init	0	1	100	31	13.2	0	0	29.4	0.68
28-Jan	11	Init	0	1	100	31	15.9	0	0	35.3	0.68
04-Feb	18	Init	0	1	100	32	20	0	0	44.4	0.73
12-Feb	26	Init	0	1	100	33	24.3	0	0	54	0.78
21-Feb	35	Dev	0	1	100	34	30.2	0	0	67	0.86
03-Mar	45	Dev	3.5	1	100	34	35.1	0	0	77.9	0.9
14-Mar	56	Dev	0	1	100	40	47.4	0	0	105.4	1.11
25-Mar	67	Dev	0	1	100	42	56.5	0	0	125.6	1.32
05-Apr	78	Mid	0	1	100	45	62.8	0	0	139.6	1.47
15-Apr	88	Mid	0	1	100	41	57.6	0	0	128	1.48
25-Apr	98	Mid	0	1	100	41	57.8	0	0	128.6	1.49
05-May	108	Mid	0	1	100	41	57.3	0	0	127.4	1.47
18-May	121	End	0	1	100	46	64.8	0	0	144	1.28
01-Jun	End	End	0	1	0	46					
Total							542.9	0	0	1206.6	14.25

Appendix Table 12: Typical soil water characteristics for different soil types

TABLE 19. Typical soil water characteristics for different soil types

Soil type (USA Soil Texture Classification)	Soil water characteristics			Evaporation parameters	
	θ_{FC}	θ_{WP}	$(\theta_{FC} - \theta_{WP})$	Amount of water that can be depleted by evaporation	
				stage 1 REW	stages 1 and 2 TEW* (Z_e = 0.10m)
	m^3/m^3	m^3/m^3	m^3/m^3	mm	mm
Sand	0.07 - 0.17	0.02 - 0.07	0.05 - 0.11	2 - 7	6 - 12
Loamy sand	0.11 - 0.19	0.03 - 0.10	0.06 - 0.12	4 - 8	9 - 14
Sandy loam	0.18 - 0.28	0.06 - 0.16	0.11 - 0.15	6 - 10	15 - 20
Loam	0.20 - 0.30	0.07 - 0.17	0.13 - 0.18	8 - 10	16 - 22
Silt loam	0.22 - 0.36	0.09 - 0.21	0.13 - 0.19	8 - 11	18 - 25
Silt	0.28 - 0.36	0.12 - 0.22	0.16 - 0.20	8 - 11	22 - 26
Silt clay loam	0.30 - 0.37	0.17 - 0.24	0.13 - 0.18	8 - 11	22 - 27
Silty clay	0-30 - 0.42	0.17 - 0.29	0.13 - 0.19	8 - 12	22 - 28
Clay	0.32 - 0.40	0.20 - 0.24	0.12 - 0.20	8 - 12	22 - 29

Source: FAO 1998

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Appendix Table 13: Infiltration measurement at head

Time (min)	Cum. Time (min)	Reading (mm)	Infiltration (mm)	Infiltration rate(mm/min)	Infiltration rate(mm/hr)	Cum. Infiltration (mm)
0	0	90	0			0
2	2	88	2	1	60	2
2	4	87	1	0.5	30	3
2	6	86.2	0.8	0.4	24	3.8
2	8	85.4	0.8	0.4	24	4.6
2	10	84.6	0.8	0.4	24	5.4
5	15	83	1.6	0.32	19.2	7
5	20	81.8	1.2	0.24	14.4	8.2
5	25	80.6	1.2	0.24	14.4	9.4
5	30	79.4	1.2	0.24	14.4	10.6
10	40	77.1	2.3	0.23	13.8	12.9
10	50	75.2	1.9	0.19	11.4	14.8
10	60	73.3	1.9	0.19	11.4	16.7
10	70	71.4	1.9	0.19	11.4	18.6
20	90	67.9	3.5	0.175	10.5	22.1
20	110	64.8	3.1	0.155	9.3	25.2
20	130	61.7	3.1	0.155	9.3	28.3
20	150	58.6	3.1	0.155	9.3	31.4
30	180	54.8	3.8	0.127	7.6	35.2
30	210	51.2	3.6	0.12	7.2	38.8
30	240	47.6	3.6	0.12	7.2	32.4
30	270	44	3.6	0.12	7.2	46

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Appendix Table 14: Infiltration measurement at middle

Time (min)	Cum. Time (min)	Reading (mm)	Infiltration (mm)	Infiltration rate(mm/min)	Infiltration rate(mm/hr)	Cum. Infiltration (mm)
0	0	90	0			0
2	2	88.3	1.7	0.85	51	1.7
2	4	87.1	1.2	0.6	36	2.9
2	6	86.2	0.9	0.45	27	3.8
2	8	85.3	0.9	0.45	27	4.7
2	10	84.4	0.9	0.45	27	5.6
5	15	82.4	2	0.4	24	7.6
5	20	80.8	1.6	0.32	19.2	9.2
5	25	79.5	1.3	0.26	15.6	10.5
5	30	78.2	1.3	0.26	15.6	11.8
5	35	76.9	1.3	0.26	15.6	13.1
10	45	74.7	2.2	0.22	13.2	15.3
10	55	72.9	1.8	0.18	10.8	17.1
10	65	71.1	1.8	0.18	10.8	18.9
20	85	68.6	2.5	0.125	7.5	21.4
20	105	66.2	2.4	0.12	7.2	23.8
20	125	63.8	2.4	0.12	7.2	26.2
30	155	60.8	3.0	0.1	6.0	29.2
30	185	57.8	3.0	0.1	6.0	32.2
30	215	54.8	3.0	0.1	6.0	35.2
30	245	51.8	3.0	0.1	6.0	38.2

`

Appendix Table 15: Infiltration measurement at tail end

Time (min)	Cum. Time (min)	Reading (mm)	Infiltration (mm)	Infiltration rate(mm/min)	Infiltration rate(mm/hr)	Cum. Infiltration (mm)
0	0	90	0			0
2	2	88.2	1.8	0.9	54	1.8
2	4	86.9	1.3	0.65	39	3.1
2	6	85.6	1.3	0.65	39	4.4
2	8	84.3	1.3	0.65	39	5.7
5	13	82.2	2.1	0.42	25.2	7.8
5	18	80.4	1.8	0.36	21.6	9.6
5	23	78.9	1.5	0.3	18	11.1
5	28	77.4	1.5	0.3	18	12.6
5	33	75.9	1.5	0.3	18	14.1
10	43	73.6	2.3	0.23	13.8	16.4
10	53	71.6	2	0.2	12	18.4
10	63	69.9	1.7	0.17	10.2	20.1
10	73	68.2	1.7	0.17	10.2	21.8
30	103	65.22	2.98	0.099	5.96	24.78
30	133	62.62	2.6	0.0867	5.2	27.38
30	163	60.02	2.6	0.0867	5.2	29.98
30	193	57.42	2.6	0.0867	5.2	32.58
30	223	54.82	2.6	0.0867	5.2	35.18

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7.2. APPENDIX FIGURES

Appendix Figure 1: photos during field data collection

Where:- a = disfunctional gate at main canal

b = Overtopping from main canal

c = Night storage

d = accumulation of silt at secondary canal

e = Intake2 at night storage

f = measurement of applied water to the farmers' field

g = poor secondary canal management

h = overtopping from secondary canal

`

7.3. QUESTIONNAIRE

Sample Questionnaire for evaluation of Golina irrigation Project

Zone... Wereda.................................

Project Name......................

Farmer Name..

Name...

A. Socio-economic Characteristics of Farmer

1. Sex composition of the household

   a. Male b. Female

2. Literacy level of the household

   a. illiterate b. read and write only

   c. elementary d. high school complete

   e. diploma and above

3. Marital status of the respondent

   a. married b. widowed c. divorced d. unmarried

4. Total land size ____________ (you can use hectare or local measurement)

5. Land under cultivation _____________

6. Fallow land ____________

7. Grazing land ___________

8. Explain the agro ecological zone of your Kebele

   a. dega b. woina dega c. kola

9. How do you evaluate sufficiency of rain fall of the area for crop production?

   a. excess b. sufficient c. in sufficient d. very low

10. Is there any record of crop failure in the area due to shortage of rain fall?

    a. Yes b. No

11. If yes, indicate the year ____

12. What is the major occupation of the household?

    a. crop production b. mixed farming

    c. livestock d. vegetable e. others

13. Do you have additional incomes that supplement your major occupation?

`

a. Yes b. No

14. How was your agricultural production for the last three years?

a. excess for annual household consumption c. sufficient for six months only

b. sufficient for annual household consumption d. sufficient for less than six months

15. If your household faced food shortage, what do you think was the reason? (Rank in order of importance)

a. land shortage b. oxen shortage c. labor shortage

d. poor productivity e. farm implements shortage f. crop failure due to erratic rain fall

g. others (specify)______________

16. What do you do to cope with the problem?

a. rent farm land b. borrow money

c. sales of cash crops d. assets sale

e. involve in off farm activity f. others (specify)………………….

B. Project Evaluation

I. Planning

17. Who initiate the idea of constructing the structures?

a. Local people d. Government

b. DA e. NGO

c. Project staff f. Others

18. If it is not the local people, have you been consulted or participated for the scheme approval?

a. Yes b. No

19. If no consulted, why..

20. If yes have you agreed?

a. Yes b. No

21. How was the planning process?

a. Group discussion c. Simple information by PA leader

b. Simple information by Das d. Simple information by project personnel

22. Have you participated in planning of any project

a. Yes b. No

`

II. Implementation

23. Do you participate in the construction of the diversion structure and irrigation canals?

a. Yes b. No

24. If yes, in what way you participate?

a. Voluntarily without payment

b. By rule without payment (mass mobilization)

c. Through payment in the form of money

d. Through payment in the form of food aid

e. Through payment in the form of Safety net program

f. Both with and without payment

25. When was the construction completed? ....

26. Were there formal handing over of the project to the beneficiaries?

a. Yes b. No

27. If no to whom did the project handover the scheme? ……………………..

28. If there was handing over, who owned the project?

a. Water User Association

b. Community Leaders

c. Others ………………………………………

d. No formal handing over

29. Do you use the irrigation project by now?

a. Yes b. No

30. If No, why? ....

`

III. Design of the project

31. Who design or put the layout of the structure?

a. DA

b. Project staff

c. Woreda expert

d. Others …………………………

32. Who developed the scheme?

a. community b. government

c. NGO d. a&b e. a&c

33. Who is the owner of the scheme?

a. community b. government

c. NGO d. a&b e. a&c

34. Do you have any specialized training on irrigation?

a. Yes b. No

35. For how long (years) you practiced irrigation? _________

36. Do the scheme has been constructed with the consent and full participation of the target beneficiaries?

a. Yes b. No

37. if yes, in what aspect did you participate

a. simply attending discussion assemblies about the project

b. attending discussion assemblies and actively expressing feelings, ideas, views.

c. acting as an informant

38. Explain the type of contribution you made for the project

a. money b. labor c. material d. land

e. a&b f. a&b&c g. all i. others_________

C. Water management

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

40. 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. Specify if any other system...

41. Are there special considerations for crop type and stage of growth during water allocation?

a. Yes b. No

42. What are the major agricultural crops you produce using irrigation? ________

43. Why do you prefer to grow such crops?

a. better price b. good production c. easy to operate

d. high disease tolerance e. seeds availability f. others (specify) ___________

44. Is there a mechanism of water pricing for irrigation users?

a. no, water is provided as a free service

b. yes, water is provided by charge but does not vary with the quantity of water used

c. irrigation water charge is based on the volume of water used

d. others (specify)__________________

45. What criteria should you used to decide when to irrigated crops?

a. wait until see signs of wilting on the leaves

b. check the soil near the roots

c. when it is dry, i irrigate

d. irrigate every day

46. Have you ever faced a problem of crop failure when using irrigation?

a. Yes b. No

47. If yes, why? (Circle as many as apply)

a. water shortage b. crop disease c. poor irrigation maintenance

d. over flooding of the farm and consequent erosion

e. others (specify) _____________

48. Are there any problem during the application of irrigation water?

a. Yes b. No

49. If yes, what are they? (rank them)--------------------------

`

a. downstream conflict b. shorter time allowed for irrigation water flow

c. water use administration problem d. lack of maintenance

e. lack of operational skill/training f. others_____________

50. Do you have labor shortage in operating your irrigation farm?

a. Yes b. No

51. What constraints affect you in using the scheme efficiently? (put in order of importance)

a. lack of input financing b. unavailability of inputs

c. shortage of labor d. lack of rural access road & high transportation cost

e. conflict in water utilization with users

f. lack of marketing for produce g. water shortage

h. others_______

D. Institutional supports

52. Do you have access to different input supply for irrigation?

a. Yes b. No

53. Did you use improved seed, fertilizer, and hand tools?

a. Yes b. No

54. Have you ever visited by an extension agent?

a. Yes b. No

55. If yes, during which operation?

a. land preparation b. planting/transplanting

c. weeding d. applying agro chemicals

e. watering f. harvesting

56. Is there nearby government/private owned large scale irrigation?

a. Yes b. No

57. If yes, do you have any relation with them?

a. Yes b. No

58. If yes, what are the fields of your cooperation?

a. field day or demonstration b. on-farm verification

`

c .market facilitation d. input provision e. others (specify)___________

59. What kind of institutional support do you need in relation to the scheme?

a. organization and management b. increase the scheme's capacity

c. maintenance d. others ____

E) Sustainability of the project

60. Do you feel that the irrigation scheme belongs to you?

a. Yes b. No

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

a. to the community b. to the government

c. to the NGOs' d. any combination of the above

62. Have you ever participated in maintenance of the irrigation scheme?

a. Yes b. No

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

a. it is not my responsibility

b. i do not know how to do it c. if there is others (specify) ------------------

F) Organizations

64. Is there water users association in your locality?

a. Yes b. No

65. If yes, are you a member of water users association?

a. Yes b. No

66. If yes, how was the association formed? ....

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

a. irrigation water on program basis b. economic water use

c. adapt social accountability and responsibility d. all

68. Do you think your WUAs strong?

a. Yes b. No