PERFORMANCE EVALUATION OF GOLDA SMALL-SCALE IRRIGATION SCHEME IN ASSOSA WOREDA, BENISHANGUL GUMUZ REGIONAL STATE, ETHIOPIA.

MSc. THESIS

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APPROVAL SHEET

As members of the Examining Board of the Final MSc. Open Defense, we certify that we have read and evaluated the thesis prepared by MINIEBEL FENTAHUN MOGES entitled " Performance Evaluation of Golda small scale Irrigation scheme in Assosa Woreda, Benishangul Gumuz Region, Ethiopia ", and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Irrigation and Drainage Engineering.

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I hereby certify that have read this thesis prepared under my direction and recommended that it accepted as fulfilling the thesis requirement.

DEDICATION

I dedicate this thesis manuscript to my father KESIS FENTAHUN MOGES and my mother EMAWAYESH BISEMAGNI for nursing me with affection and love and for their dedicated partnership in the success of my life.

STATEMENT OF AUTHOR

I, the researcher, Miniebel Fentahun Moges declare that, this thesis is my own original work and it is not presented and will not be presented to any other University for perusing similar degree award. Moreover, all the source of materials used for the thesis are duly acknowledged.

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BIOGRAPHICAL SKETCH

The author was born on March 23, 1990 at Merawi West Gojjam, from his father kesis Fentahun Moges and his mother Emawayeshe Bisemagn. He attended his elementary education at Sibu elementary school and Wotet Abay senior elementary school. He followed his secondary education at Merawi Secondary and preparatory School. After completing his preparatory school education in 2009, he joined Debire Birhan University in October 2010 and graduated with BSc. degree in Water Resource and Irrigation Management in July 2013.

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ACRONYMS AND ABBREVIATIONS

BD	Bulk Density
^{o}C	Degree Celicius
Cm	Centimeter
CWR	Crop Water Requirement
Dr	Distribution Ratio
Du	Distribution Uniformity
Ea	Application Efficiency
Ec	Conveyance Efficiency
EARO	Ethiopian Agricultural Research Organization
Es	Storage Efficiency
ETc	Evapotranspiration Crop
FAO	Food and Agricultural Organization
FC	Field Capacity
Ha	Hectar
ISRIC	International Soil Reference and Information Center
Kc	Crop Coefficient
Km	Kilometer
LQ	Low Quarter
M	Meter
MAD	Manageable Allowed Deficit
Max	Maximum
m.a.s.l	Meter Above Sea Level
Mha	Million Hectares
Min	Minimum

mm	Millimeter
MoA	Federal Democratic Republic Ethiopia Ministry of Agriculture
MoARD	Ministry of Agricultural and Rural Development
MoWR	Ministry of Water Resource
NGOs	Non-governmental Organizations
NIR	Net Irrigation Requirement
PWP	Permanent Wilting Point
Rf	Runoff Fraction
RH	Relative Humidity
RR	Runoff Ratio
RWS	Relative Water Supply
SIA	Sustainability of Irrigated Area
SSI	Small Scale Irrigation
SSIS	Small Scale Irrigation Scheme
UK	United Kingdom
WUAs	Water Users Association

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PERFORMANCE EVALUATION OF GOLDA SMALL SCALE IRRIGATION SCHEME IN ASSOSA WOREDA, BENISHANGUL GUMUZ REGIONAL STATE, ETHIOPIA

ABSTRACT

Evaluation of the performance of irrigation schemes helps to know the present status of the scheme and to apply possible measures for improvement. Golda small scale irrigation scheme was found in Assosa, Benishangul Gumuz regional state, Ethiopia and had a service of six years. The performance of Golda Small Scale Irrigation Scheme had not been evaluated before this study. Therefore, this study was conducted to evaluate the scheme by considering water delivery performance, on field water management performance and organizational setups and their performance for irrigation water management and maintenance. Primary data collected through field measurements and household field survey, and secondary data from different sources were used. Water delivery was evaluated by external indicators such as conveyance efficiency, relative water supply and relative irrigation supply. Both internal and external indicators were used for evaluating on field water management performance. The internal indicators were application efficiency, storage efficiency, distribution uniformity and deep percolation ratio. The external indicators like agricultural out puts, physical and financial indicators were used. The result of conveyance efficiency, application efficiency, storage efficiency, distribution efficiency and deep percolation ratio, were 53%, 51.6%, 91.6%, 80.76% & 40% respectively. The value of relative water supply and relative irrigation supply were 1.6 and 1.2 respectively. The result of output per unit command area, output per unit irrigated area, output per unit water supply and output per unit water consumed were 3542.66US$, 4306.76US$, 1.42 and 0.69, respectively. The result of the physical indicators, which were irrigation ratio and sustainability of irrigated area, were found to be 0.82 and 1, respectively. Around 54% of gross return on investment was obtained.. About 67.6% of respondents reflected the maintenance condition of the irrigation scheme was bad. Unfair distribution of water was due to water scarcity and illegal water users as the beneficiaries responded. Generally, the scheme requires improvement measures.

Keywords: efficiency, external indicators, internal indicators, irrigation, performance, SSIS

1. INTRODUCTION

1.1. Background

Ethiopia is endowed with ample water resources. Although it needs further detailed investigation, according to the current knowledge, the country has about 124.4 billion cubic meter (BCM) river water, 70 BCM lake water, and 30 BCM groundwater resources (Belete *et al.*, 2014). The water resources potential and its utilization rate are in comparable in the country. There are huge amounts of both surface and ground water resources but the utilization of it is in infant rate. It is clearly marked that the economic development of the country is never go far without utilization of water resources properly. But under current situation, the country is not used their water resources properly due to different political, natural, technical and economic factors. On the other side, the water sector development programs are performing well to increase the utilization potential and at the same time there are different eye opening future opportunities to develop the water resources development and utilization (Ayalew, 2018).

The land of Ethiopia under cultivation is estimated to be about 12 million ha (MoA, 2011a). Moreover, even though the potential and actual irrigated areas are not precisely investigated (Belay and Bewket, 2013), estimates of irrigable land in Ethiopia vary between 1.5 and 4.3 million hectares (Mha), the average being about 3.5 Mha (MoWR, 2001; Werfring, 2004; Awulachew et al., 2005; Makombe *et al*., 2011). However, the total land under irrigation is estimated to be in the range between 160,000-200,000 ha which is less than 5% of the country's irrigable land (Awulachew *et al*., 2005, 2007; World Bank, 2006; Makombe *et al*., 2007).

According to MoA (2011a), about 10-12% of the total irrigable potentials are under production using traditional and modern irrigation schemes. Moreover, differences in irrigation potentials and actually irrigated lands, for example 3.7 Million ha and 197,000 ha according to Awlachew *et al*. (2007) and 3.5 Million ha and 626,116 ha as reported by Hagos *et al*. (2009), respectively, have indicated differences in the same class. Improved small scale irrigation schemes (<200ha) in Ethiopia were constructed mainly by the government, NGOs' and other donors to increase the crop production and productivity. In some places, traditional small scale irrigations are constructed through the community members (MoA, 2011)**.**

According to Haile and Kassa (2015), the policies and strategies of Ethiopia strongly support irrigation developments especially small scale irrigation (SSI) through the Water Sector Development Programs (WSDP) and Ethiopian Irrigation Development Plan (IDP). This irrigation development is mainly expressed in the development of small scale irrigation (SSI) schemes by the government, donors and Non-Governmental Organizations (NGOs).

Irrigation is believed as the key for food security and poverty reduction in Ethiopia. As a result, developments in the Ethiopian irrigation system have shown great advancements so as to assure Ethiopian livelihoods especially in the rural areas. This indicates that more investment on the area have paramount importance for the development of the country. Generally, the government and the peoples of Ethiopia believe that irrigation can play a significant role for food security enhancement and economic growth. Therefore, intensive investments should be operated in the sector by governmental, non-governmental and private investors.

Generally, International Water Management Institute developed two types of indicators to evaluate irrigation systems: internal and external indicators. The aim of applying external indicators is to evaluate outputs and impacts of irrigation management practices, interventions across different systems and system levels, as well as to compare various irrigation seasons and technologies with one another while internal indicators are used to assess actual irrigation performance relative to system specific management goals and operational target (Kloezen *et al*., 1998).

1.2. Statement of the Problem

Poor irrigation water management associated with water scarcity is the major reason for underperformance of most small-scale irrigation schemes in Ethiopia (Fissahaye *et al*., 2017). In Ethiopia, scheme performance is estimates on average 36% below design capacity, implying a loss of about 230,000ha of irrigated land, leading to only 410,000ha irrigated. Small scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew *et al*., 2010a; 2010b). Poor management of available water for irrigation, both at system and farm level has led to a range of problems and further aggravated water availability and has reduced the benefits of irrigation investments (FAO,1996).

In BenishangulGumuz Regional State, AssosaWoreda, there are eight small scale irrigation schemes. Seven small scale irrigation schemes were constructed by the Regional Bureau of

Agriculture and one small scale irrigation scheme was constructed by World Vision. Golda small scale irrigation scheme is one of the schemes constructed by the Regional Bureau of Agriculture (Source: Assosa Agricultural Office).

Evaluating and improving the performance of existing schemes is an attractive way for sustainable development and used as a bench mark or point of entry for further irrigation development. The Irrigation schemes are being under low productivity due to absence of experience in design, operation, maintenance and limitation on modern irrigation water management, (irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques), and low irrigation performance of schemes (Awulachew, 2010; MoA, 2011). The performance of the entire irrigation scheme is not according to the intended objectives if the scheme is not managed and operated properly. Many irrigation schemes, particularly in least developed and emerging countries, are characterized by a low level of overall performance (Dejen, 2015; 2016).

The evaluation of existing functional and non-functional small scale irrigation schemes is relevant for improving its performance, increasing the productivity and water productivity. More generally, there are many factors accountable for the poor performance of irrigation schemes at the existing conditions. Despite the poor performance of the irrigation schemes in the Woreda, evaluation of small scale irrigation schemes and benchmarking of the results is not common; this is particularly true in using the performance indicators**.** This study aims to undertake performance evaluation of Golda small scale irrigation scheme.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study was to evaluate the performance of Golda small scale irrigation scheme in Assosa Woreda, Benishangul Gumuz Regional State, Ethiopia.

1.3.2. Specific objectives

The specific objectives of this study were:

- To evaluate the water delivery performance of Golda small scale irrigation scheme using performance indices
- To evaluate on-field water management performance of Golda small scale irrigation scheme with performance indices
- To evaluate organizational setup and performance for irrigation water management and scheme maintenance

1.4. Research Questions

1. How is the water delivery performance of the scheme?
2. How is on-field water management performance?
3. How is the irrigation scheme organization contributing to the management and sustainability of the scheme?

1.5. Significance of the Study

This study will provide information about the performance of the current irrigation scheme under investigation. The results of the study will have significant contribution to understand the drawbacks and best achievements across system levels. And also, it will give insights about the impacts of intervention and directions for policy makers. Moreover, it will provide information for further improvement and investment approaches for implementing agencies. This study will also provide a good input at times of planning for future irrigation projects aimed at foreseeing their future performance. On top of these, the study will be used as a benchmark and entry point for development works and future studies.

2. LITERATURE REVIEW

2.1. Irrigation Conditions in Ethiopia

Irrigation development is vital to the sustainable and reliable agricultural developments in Ethiopia. Subsistence dominated smallholder farmers' economy can be improved through the use of irrigation in the Ethiopian agriculture (MoA, 2011b). Similarly, making use of irrigation agriculture is going to be a means for increased agricultural production to meet the growing food demands of rapid population growth. Irrigation development in Ethiopia can be considered as a cornerstone of food security and poverty reduction tool as it has a power to stimulate economic growth and rural developments (Hagos *et al*., 2009), as cited by Haile and Kasa (2015). As a result, irrigation infrastructures are increasing year after year, which show country wide positive development implications and experiences in small and large scale irrigation schemes.

In Ethiopia, farm size per household is 0.5 ha and the irrigated land per households' ranges from 0.25 - 0.5 ha in the Ethiopian context (MoA, 2011a). As a result, individual land holdings per households are too small to feed the household. With this limited land holdings, increasing food demands of the population depends on either one or a combination of increasing agricultural yield, increasing the area of arable land, and increasing cropping intensity by growing two or three crops per year using irrigation (MoA, 2011a).

Nata *et al.* (2007) and Abraham *et al*. (2011) listed out the benefits of irrigation that include: increases food production in arid and semi-arid regions, enhances food production, promotes economic growth and sustainable development, creates employment opportunities, and improves living conditions of small-scale farmers. As a result, irrigation contributes to poverty reduction and protects the environment from degradation and pollution. Furthermore, it increases subsurface water levels and recharges groundwater. As a result, small, medium and large scale irrigation infrastructure needs to be developed in the country. This helps to produce export commodities that would earn foreign exchanges and provides raw materials to the local industries.Since, most of the irrigation development in Ethiopia is expressed through an expansion of small-scale irrigations, medium and large scale irrigation developments are needed to be taken into consideration. On the other way, irrigation development in Ethiopia is in its infancy stage (MoA, 2011a).

The Ethiopian government is therefore pursuing plans and programs to develop irrigation in an effort to substantially reduce poverty and create an atmosphere for social change. As a result, the Ethiopian average rate of irrigation development for the last 12 years has been about 1,090-1,150 ha/year (Nata *et al.*, 2008; Bekele *et al*., 2012). In Ethiopia, only 10% of the estimated potential irrigable land is actually irrigated (Gebremedhin and Pedon, 2002) and 2% of cultivated lands are irrigated (MoWR, 2001). Similarly, irrigated agriculture comprises only 3% of the total national food production (Bacha *et al*., 2011). That is why irrigated agriculture is far from satisfactory, despite the considerable investment, public interest, and strategic support of the government.

Belay and Bewket (2013) explained that irrigation water is critical to poverty alleviation through increased production in rural areas so as to improve food security and rural livelihoods. Smallholder irrigation has recently received significant focus from local governments to enable farmers to cultivate crops twice or more per year. Bacha *et al*. (2011) in the study of the impact of small-scale irrigation on household poverty in central Ethiopia, reported that land productivity, asset ownership, credit utilization, extension support, resilience to poverty, mean off-farm income, and mean food consumption and expenditure on food and non-food assets were significantly higher for irrigators than non-irrigators.

2.2. Irrigation Water Management

According to United Sates Bureau of Reclamation (2005), Irrigation water management is the act of timing and regulating irrigation water applications in a way that will satisfy the water requirement of the crop without the waste of water, soil, plant nutrients, or energy. It means applying water according to crop needs in amounts that can be held in the soil available to crops and at rates consistent with the intake characteristics of the soil and the erosion hazard of the site. Management is a prime factor in the success of an irrigation system. Large quantities of water, and often large labor inputs, are required for irrigation. The irrigator can realize profits from investments in irrigation equipment only if water is used efficiently. The net results of proper irrigation water management typically:

- Prevent excessive use of water for irrigation purposes
- Prevent irrigation induced erosion
- Reduce labor

- Minimize pumping costs
- Maintain or improve quality of ground water and downstream surface water
- Increase crop biomass yield and product quality

Tools, aids, practices and programs to assist the irrigator in applying proper irrigation water management include: U.S Bureau of Reclamation (2005):

- Applying the use of water budgets or balances to identify potential water application improvements.
- Applying the knowledge of soil characteristics for water release, allowable irrigation application rates, available water capacity, and water table depths
- Applying the knowledge of crop characteristics for water use rates, growth characteristics, yield and quality, rooting depths, and allowable plant moisture stress levels.
- Water delivery schedule effects
- Water flow measurement for on field water management
- Irrigation scheduling techniques
- Irrigation system evaluation techniques

2.2.1. Irrigation scheduling

Irrigation scheduling is the practice of using some method to decide when to start an irrigation system and how much water to apply. No matter what method is used, they all start with knowing when and how much rain has been received on the field and then using some mechanism to decide when to irrigate (Thomas *et al*., 1999).Irrigation scheduling is the use of water management strategies to prevent over application of water while minimizing yield loss due to water shortage or drought stress. Some irrigation water is stored in the soil to be removed by crops and some is lost by evaporation, runoff, or seepage. The amount of water lost through these processes is affected by irrigation system design and irrigation management. Careful scheduling minimizes runoff and percolation losses, which in turn usually maximizes irrigation efficiency by reducing energy and water use.

The adoption of appropriate irrigation scheduling practices could lead to increased yields and greater profit for farmers, significant water savings, reduced environmental impacts of irrigation and improved sustainability of irrigated agriculture (Smith *et al*., 1996). Irrigation scheduling is an important irrigation management issues for maximizing production efficiency. It involves determining the proper amount and timing of water applications throughout the growing season.

In water stress sensitive crops such as vegetables grown for their fresh leaves or fruit, growers should schedule irrigations very carefully to avoid losses from over or under watering. To avoid over or under irrigation, it is important to know how much water is available to the plant, and how efficiently the crop can use it. There are many methods available to measure these factors. They include direct measurements such as plant observation, feel and appearance of the soil, and using soil moisture monitoring devices; or indirect measures which estimate available water from weather data. Determination of the appropriate timing of irrigation usually involves the use of daily ET estimate based on local meteorological data to maintain a daily soil water balance throughout the irrigation season.

2.3. Types of Irrigation Schemes

There are different criteria's for the classification of irrigation schemes around the world. The main criteria's frequently used for the classification of irrigation schemes are the irrigated area, scale of operation and management types. The most commonly used classification is small, medium and large scale irrigation schemes, though the interpretation of these categories may vary from country to country. For example, in Ghana an irrigation scheme of 300 ha is classified as small-scale, whereas in India 10,000ha is categorized as small-scale (Smith, 1998). In Ethiopia during the Dergue regime, irrigation schemes were categorized into three types based on size into small-scale (<200 ha), medium scale (200-3000 ha) and large scale (>3000 ha) (Rahemeto, 1999).

Another classification takes into account size and management (Werfring *et al*., 2004):

- Traditional small-scale irrigation schemes up to 100 ha built and operated by farmers in local communities.
- Modern commercial schemes up to 200 ha built by Government agencies with farmer participation.
- Modern private schemes up to 2,000 ha owned and operated by private investors individually, in partnership, or as corporations.
- Public schemes of over 3,000 ha owned and operated by public enterprises as state farms.

2.3.1. Small scale irrigation scheme

According to Lam (1996), the definition of "small scale irrigation systems "varies, depending on the way that specific country defines it. On another view, various criteria are used in referring to small scale irrigation and defining as the process of introducing effective water control technique to schemes with an independent water supply and area not exceeding 50ha, which are to be planned, developed and managed by farmers through the establishment of viable Water User Association (WUA) linked to existing social structure (FAO, 1998). According to FAO (1998), small scale irrigation can be highly cost effective when simple locally adapted techniques are used and that quick return can be expected as planning and design is implemented at local level with farmers directly contributing towards the construction. This also plays a vital role in poverty alleviation and improving the nutritional conditions of the rural poor who often do not receive the common benefits of economic growth.

According to Ethiopian irrigation scheme classification, small-scale irrigation scheme (SSI) is defined as the area less than 200 ha which are often community based and traditional methods. Traditional irrigation has a long history in Ethiopia. During the Derg Regime, very little attention was paid to small scale and traditional irrigation schemes constructed and managed by peasant farmers. The traditional small scale irrigation uses simple water diversions. It has been practical for decades in the high land where small farms could divert river, spring water seasonally for a limited dry season cropping.

Construction of small scale irrigation schemes are the responsibility of Ministry of Agricultural and Rural Development (MoARD) and Regions (MoWR, 2002). Small-scale systems and technologies are attractive since they put the operation, maintenance and management of systems directly in the hands of the individual farmers, thus eliminating any need for centralized control or management (Jorma, 1999).

In general, according to McCornick *et al.* (2003) all small-scale systems may have advantages over large-scale systems. These advantages include that small-scale technology can be based on farmers existing knowledge; local, technical, managerial and entrepreneurial skills can be used; migration or resettlement of labor is not usually required; planning can be more flexible; social infrastructure requirements are reduced; and external input requirements are lower. According to

Yalew (2006), there is also limited supply of agricultural inputs and credit services on SSI schemes. There is no production plan, which severely affects the production market of SSI schemes. In general, the extension service became weak or eliminated whenever small scale irrigations are implemented.

2.3.2. Medium scale irrigation scheme

According to Ethiopian irrigation scheme classification, medium scale irrigation scheme refers to irrigated areas covering 200 to 3,000ha which is community based (Awulachew *et al.*,2010b).

2.3.3. Large scale irrigation scheme

According to MoWR of Ethiopia, large scale irrigation scheme refers to lands covering more than 3,000 hectares, which is typically, commercially or publicly sponsored (Awulachew *et al.*, 2010b).Several important benefits accrue from medium and large-scale irrigation that are relevant in the context of the Ethiopian irrigation sector, including: per hectare investment is less costly than the isolated small-scale schemes, particularly when compared with deep groundwater or small dams, and large-scale schemes can break the relationship between agricultural growth and rainfall. However, critics of medium and large-scale irrigation argue that such schemes are to the benefit of commercial farms instead of smallholders. Additionally it has impacts of migration or resettlement of labor, planning is more complex, requires high initial investment cost and social infrastructural requirement increase.

2.4. Performance Evaluation of Irrigation Schemes

According to Molden (1998), Performance is assessed for a variety of reasons: to improve system operations, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess 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.

Evaluations are useful in a number of analyses and operations, particularly those that are essential to improve management and control. Evaluation data can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year (FAO, 1989). As many farmer managed irrigation scheme do not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement (Jorge, 1993).

Public agencies in many developing countries want to assist farmer-managed irrigation systems improve their performance through better management. And, better management is dependent upon appropriate methods and measures by which system performance can be evaluated relative to the management objectives (Oad and Sampath, 1995). 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 setbacks that hinder the introduction of small-scale irrigation.

2.5. Performance Indicators

2.5.1. General features of performance indicators

To carry out performance evaluation of irrigation schemes, 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 concluded that the services provided by the system and the appropriate performance standards are greatly influenced by the design of that system. Efforts have been made over the years to develop appropriate evaluation models that could use the irrigation parameters and variables to evaluate irrigation performance. Among these, the volume balance model is the basis for most design and field evaluation procedures. This has been proven with field and laboratory data. It allows quick and reliable definition of infiltration rates over the length of the field and it is easily extended to indications of uniformity and efficiency parameters (Walker and Skogeroboe, 1987).

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. In response to the insufficient performance of existing irrigation system, focus was made on the performance evaluation of the schemes. However, in conducting performance of irrigation, more than one view point exists. In addition, few of these criteria reflect the view of the farmers (Gowing *et al*., 1996). It is therefore essential that evaluation of the performance of surface irrigation system be continued with a view to improve the performance of the systems.

According to Yashima (1997), performance indicator is the response to 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. As Burt and Styles (1999) cited, Murray-Rust and Snellen (1993) described the framework of using performance indicators, and noted two approaches to the use of performance indicators in the field of irrigation:

I. Attempts to develop indictors which allow the performance of one system to be compared to similar systems elsewhere

II. The use of indicator to compare actual results with what was planned.

Bos *et al*. (1994) mentioned that dividing the system into several sub-systems, 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 indictors in the form of a ratio of the actually measured versus the intended situation (Bos, 1997).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 indictors can, and should, be used in a spatial context whenever equity is included in the objective set. Bos *et al*. (1994) confirmed that using performance indicators in a spatial dimension also enables managers to identify precise locations at which problems are arising, and where to take remedial action. Dividing the system into several sub-systems, and assessing the performance at these lower levels, helps describe system performance more effectively. The common efficiency terms used for on-farm irrigation system evaluation include application efficiency, uniformity and storage efficiency, recently complementary terms such as runoff ratio and deep percolation ratio are being applied (Jurriens *et al*., 2001).

2.5.2. Properties of performance indicators

Some of the desirable attributes of performance indicators suggested by Bos (1997) are: Scientific basis: the indicator should be based on an empirically quantified, statistically tested causal model of that part of the irrigation process it describes. The indicators must be quantifiable: the data needed to quantify the indicator must be available or obtainable (measurable) with available technology. The measurement must be reproducible. Reference to a target value: this is, of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator.

These target values and their margin of deviation should be related to the level of technology and management (Bos *et al.*,1991). Provide information without bias: ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain value judgments. Ease 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 finances, equipment, and commitment of human resources, should be well within the agency's resources.

2.5.3. Types of performance indicators

2.5.3.1. Internal performance indicators

Many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated; and cropping patterns. A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of system management, and performance measures tell how well the system is performing relative to these targets.

When the performance is not adequate, either the process must be changed to reach the target, or the target itself must be changed. These "internal" indicators aid irrigation system managers to answer the question "Am I doing things right?"(Murray-Rust and Snellen,1993).We could conclude, although it would be premature, that these internal indicators do not lend themselves well to cross-system comparison. This is due to several reasons:

- Internal processes of irrigation systems vary widely from system to system, so that performance indicators are tailored to meet system-specific needs.
- Indicators related to irrigation processes tend to be data intensive and it is often difficult, time consuming, and expensive to obtain complete data sets.
- Assumptions about relations between internal processes and outputs may not be valid. It is often assumed that meeting a target will improve output in terms of agricultural production or net benefit to farmers.

The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field (Feyen and Zerihun, 1999).

1. Irrigation efficiency

As Michal *et al*.(1972) stated that, the design of irrigation system, the degree of land preparation , and the skill and care of the irrigator are the principal factors influencing irrigation efficiency. Loss of irrigation water occurs in the conveyance and distribution system, non-uniform distribution of water over the field, percolation below crop root zone. Loss by runoff at the end of irrigation borders, furrows and field channels may also occur some times. The losses can be held to a minimum by adequate planning of the irrigation system, proper design of the irrigation method, and efficient operation of the system.

The common efficiency terms used for on-field irrigation system evaluation include application efficiency, uniformity, storage efficiency, and adequacy, and recently complementary terms such as runoff ratio, deep percolation ratio, etc. are being applied (Jurriens *et al.*,2001). Michael (1997) also put as a remark that the primary performance indicators are: storage efficiency, application efficiency and distribution efficiency.

1.1. water application efficiency (Ea)

After the water reaches the field supply Channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the water application efficiency. Water application efficiency below 100 percent are due to seepage losses from the field distribution channels, deep percolation below the crop root zone and runoff loses from the tail end of borders and furrows (in very long fields). Losses from the field occur as deep percolation beyond the root zone and as field tail water or runoff.

To compute application efficiency (Ea*)* it is necessary to identify at least one of these losses as well as the amount of water stored in the root zone (FAO, 1989). This implies that the difference between the total amount of root zone storage capacity available at the time of irrigation and the actual water stored due to irrigation be separated, that is, the amount of under-irrigation in the soil profile must be determined as well as the losses. Application efficiency (Ea) does not include losses from the conveyance networks.

Kenneth (1988) indicated that attainable water application efficiencies vary greatly with irrigation system, type and management, and suggested that the attainable application efficiency for surface irrigation are 80-90%, 70-85% and 60-75% under basin, Border and furrow type of system respectively. Norman (1999) said that a minimum value of the ratio of crop water demand to the actual amount of water supplied to the field of 0.6 (or irrigation efficiency of 60%) is included in the design of most surface irrigation systems to accommodate crop water needs and anticipated losses. Value below this limit would normally be considered unacceptable.

In general, according to Michael (1997) water application efficiency decreases as the amount of water applied during each irrigation increases.

1.2. Water storage efficiency (Es)

Small irrigation may lead to high water application efficiencies, yet the irrigation practice may be poor. The concept of water storage efficiency is useful in evaluating this problem. This concept relates how completely the water needed prior to irrigation has been stored in the root zone during irrigation. Water storage efficiency becomes important when water supplies are limited or when excessive time is required to secure adequate penetration of water in to the soil. Also, when salt problems exist, the water storage efficiency should be kept high to maintain favorable salt balance.

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

Water stored in the root zone is not 100% effective, (FAO, 1992), evaporation losses may remain fairly high due to the movement of soil water by capillary action towards the soil surface. Water lost from the root zone by deep percolation where ground water is deep. Deep percolation can still persist after attaining field capacity.

1.3. Water distribution efficiency (DU/E_d)

This shows how uniformly water is applied to the field along the irrigation run. In sandy soils there is generally over irrigation at upper reaches of the run when as in clayey soils, there is over- irrigation at the lower reaches of the run. According to Solomon (1983), uniformity is related to crop yields through the agronomic effects of under and over-watering. Insufficient water leads to high soil moisture tension, plant stress and reduced crop yields. Excess water may also reduce crop yields below potential levels through mechanisms such as leaching of plant nutrients, increased disease incidence or failure to stimulate growth of commercially valuable parts of the plant. FAO (1992) suggested that having average distribution efficiency of 65% is sufficient for furrow irrigation.

1.4. Project efficiency (Ep)

This shows how efficiently the water source used in crop production. It shows the percentage of the total water that is stored in the soil and available for consumptive requirements of the crop. It indicates the overall efficiency of the systems from the head work to the final use by plants for Consumptive use. The overall project efficiency must be considered in order to fix the amount of water required at the diversion head work.

1.5. Deep percolation ratio (DPR)

Depending on the chemical nature of the groundwater, deep percolation can cause a major water quality problem of a regional nature. The loss of water through drainage beyond the root zone is reflected in the deep percolation ratio.

2.5.3.2. External performance indicators

An approach to cross-system comparison is to compare outputs and impacts of irrigated agriculture. “External” indicators are used to relate outputs from a system derived from the inputs into that system. They provide little or no detail on internal processes that lead to the output. For example, the critical output of an irrigation system is the supply of water to crops. This output in turn is an input to a broader irrigated agricultural system where water combined with other inputs, leads to agricultural production. As irrigated agriculture always deals with water and agricultural production it should be possible to develop a set of external indicators for cross-system comparison.

A. Water delivery indicators

According to Levine (1982) and Perry (1996), conveyance efficiency (Ec), relative water supply (RWS) and relative irrigation supply (RIS) could be used for evaluation of water delivery performance . RWS and RIS relate supply to demand, and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched. Care must be taken in the interpretation of results: an irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate appropriate use of available water, and a lower RWS would actually be less desirable. Likewise, a value of 0.8 may not represent a problem, rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water (Molden *et al.*,1998). Clemmens and Molden (2007) suggested that these two indicators provide a general sense of whether there is an adequate amount of water or whether the amount of irrigation water supplied is excessive.

I. Conveyance efficiency (Ec)

Water conveyance efficiency (Ec) is the ratio in percent of the amount of water delivered by a channel to the amount of water delivered to the conveyance system. This term is used to measure the efficiency of water conveyance system associated with the canal network, water courses and field channels. It is also applicable where the water is conveyed in channels from the well to the individual fields. It is one of the several closely related and commonly used output measures of performance that focus on the physical efficiency of water conveyance by the irrigation system (Bos, 1997). Losses of irrigation water in the conveyance system can be a major component of the overall water losses particularly for farms located at significant distances from water sources where the main canals are long and unlined.

The amount of water lost depends on quality of operation, maintenance and the nature of the soil that affects the seepage rate. In Tanzania, a survey of the efficiency of improved and unimproved small-scale irrigation schemes indicated that the conveyance efficiency for the main canals and the field canals (unlined) were 84 and 65% during the dry season and 85 and 74% during the wet season respectively. However, typical conveyance efficiency values generally reported are 70 and 50% for unlined poorly managed main and field canals respectively, while for the well managed canals the figures are 85 and 80% respectively (MoAFS, 2002). FAO (1989b) recommended values of conveyance efficiency for the lined and unlined canals are given in (Table 2.1) below:

Table 2.1: Values of water conveyance efficiency as recommended by FAO (1989b)

		Unlined /Earthen canals		
	Lined canal	Soil type		
Canal length(m)		Sand	Loamy	Clay
Long > 2000	95%	60%	70%	80%
Medium (200- 2000)	95%	70%	75%	85%
Short (< 200)	95%	80%	85%	90%

II. Relative water supply (RWS)

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

III. Relative irrigation supply (RIS)

RWS and RIS values indicate whether there is an adequate supply done or not to cover the demand. RWS and RIS values of one or higher indicates adequate while the values smaller than one indicate inadequate supply of irrigation.

B. On field water management indicators

Kenneth (1988) suggested that effective irrigation management requires reliable performance assessment. Good farm irrigation management assures correct frequency of irrigations, correct application depth, uniform irrigation, minimum runoff and minimum deep percolation except for that required for salt management, minimum erosion and optimal return on irrigation investment.

I. Agricultural output indicators/Land and water productivity

It expresses output of irrigated area in terms of gross or net value of production measured at Local or world prices. This addresses the direct impact of operational inputs in terms of such aspects as area actually irrigated and crop production, over which an irrigation manager may have some but not full responsibility (Molden *et al.*,1998). The four basic external performance indicators relate output to unit land and water are listed below. These “external” indicators provide the basis for comparison of irrigated agriculture performance. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important (Molden *et al*.,1998).

1. Output per unit irrigated area

Molden *et al*. (1998) stated that it is land productivity indicator and important when land is a constraint. It can be calculated as the total value of production per harvested area in the irrigation season. The harvested /Irrigated / area includes the areas that were irrigated in the irrigation seasons. The annual harvested area depends on the cropping intensity. The area is the sum of all the areas under crops during the year in this case. This indicator is not affected by the intensity of cropping/ irrigation (Molden *et al*.,1998).

2. Output per unit command area

This is more relevant for land is the major constraint factor for production. It is the value of agricultural production per unit of nominal area, which can be irrigated. The computed value indicates the level of utilization or number of cropping frequency of the given command area in the production year and the productivity of the command area. Smaller values of this indicator can also imply, less intensive irrigation and high value result shows there is good intensive irrigation (Molden *et al*.,1998).

3. Output per unit irrigation supply

It is one of water productivity indicator which indicates how well the total annual diverted irrigation water from a source is productive. This is important parameter when water is scarce and calculated as the total value of production per unit water diverted from the headwork to the command area throughout the irrigation seasons (Molden *et al*.,1998).

4. Output per unit water consumed

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

II. Physical performance indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons.

1. Irrigation ratio (IR)

Irrigation ratio is the ratio of currently irrigated area to irrigable command area. As Sener *et al*.(2007) suggested that a high irrigation ratio can be achieved by effective water delivery in the scheme. There is no irrigation water fee that promotes farmers to use the irrigation water efficiently so as to increase the irrigable land in the scheme. Dejen *et al*. (2012) and Alemayehu (2018) at Golgota and Godana irrigation schemes respectively have found similar reasons for the greater irrigation ratio which could be explained by three factors; these are, generous water availability, absence of irrigation water fee and better land productivity encouraging farmers to invest on more areas.

In order to raise irrigation efficiency and the irrigation ratio, on-farm developments and practices should carefully be monitored and evaluated. Training and extension of farmers and irrigation managers in technical and economical considerations are also vital to the augmentation of the irrigation ratio (Değirmencİ *et al.*,2003).

2. Sustainability of irrigated area (SIA)

Sustainability of irrigated area is the ratio of currently irrigated area to initially irrigated area when designed (Bos *et al*.,2005). It is a useful indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated area and would imply more sustainable irrigation.

Dejen *et al*.(2016) suggested that the degree to which the initially planned (irrigated) area of schemes is sustained years after the implementation of a scheme is an important issue for the success of an irrigation scheme; in principle, neither extension nor shrinkage is desired, particularly where schemes are well planned and command areas were defined based on land suitability and water availability. The major factors that can contribute to shrinkage of irrigated land would be: water shortage (unreliability), lack of proper maintenance of infrastructure for water conveyance and distribution, lack of interest in irrigation when it is not paying back (for example poor access to marketing system),etc.

III. Financial indicator

1. Gross return on investment (GRI)

Researchers would like to be able to recommend systems that yield acceptable returns within a given environment. Water delivery infrastructure to be able to analyze differences between various types of delivery systems such as structured, automated, lined, and unlined canal sections. Infrastructure related to river diversions, storage and drainage is not included , because of the desire to be able to compare different methods of water delivery. Also, diversion and storage works often serve other non irrigation purposes so their costs cannot be entirely allocated to irrigation. The cost of the distribution system can either be estimated from original costs, or estimated by using present costs of similar types of infrastructure development (Molden *et al.*,1998).

2.5.3.3. Organizational indicator

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

1. Water users' associations (WUAs)

Water user association is a user-based organization that aims to manage the irrigation system for its members mostly on a nonprofit basis. A WUA is generally small in scale with a limited number of members (usually no more than several hundred members), so that self-management by users is possible. The actual size of a WUA often depends on the irrigation system. For example, a WUA may be responsible for one tertiary block that is subdivided into smaller units of Water User Groups (WUGs), or one WUA may be responsible for the entire system (Aarnoudse *et al*.,2018).

1.1.Function of WUAs

Its main tasks include (Aarnoudse *et al*.,2018):

- ✓ the allocation of water within the irrigation system,
- ✓ operation and maintenance (O&M) of the system and
- ✓ the cost recovery of O&M through the collection of irrigation fees from its members.

According to FAO (1996), developing, operating and maintaining an irrigation scheme almost always requires joint action by the water users. In traditional irrigation schemes, farmers would get together to build a diversion weir across a river or dig an access canal, because these were things they could not accomplish on their own. Without a capacity for organization and decision making among the users, it was simply not possible to complete a scheme. This capacity helped users to develop an organization capable of operating and maintaining the scheme.

In a modern scheme where most of the preparation and construction is done by a government agency, the water users have much less experience in organizing themselves. Yet the fact that in such schemes the water is usually delivered to a group of farmers requires a water users' association that is capable of assuming responsibility for water distribution among farmers. In many cases, the WUAs are also responsible for maintenance and for collecting irrigation fees from its users. WUAs could also play an important role in negotiating with the scheme operators on the service agreement (FAO, 1996).

Many conflicts occur due to the problem of water theft or unauthorized canal breaching in the scheme. There is a conflict resolution mechanism and most WUAs develop their by-laws which is a system rules for controlling the conflict within the scheme. The WUAs committees have long existed to manage SSI schemes. They are generally well organized and effectively operated by farmers. The associations handle construction, allocation, operation and maintenance functions with government technical and material support (MoWR, 2002).

In Ethiopia, there is a proclamation No.841/2014 on the formulation and administration of irrigation water users associations.

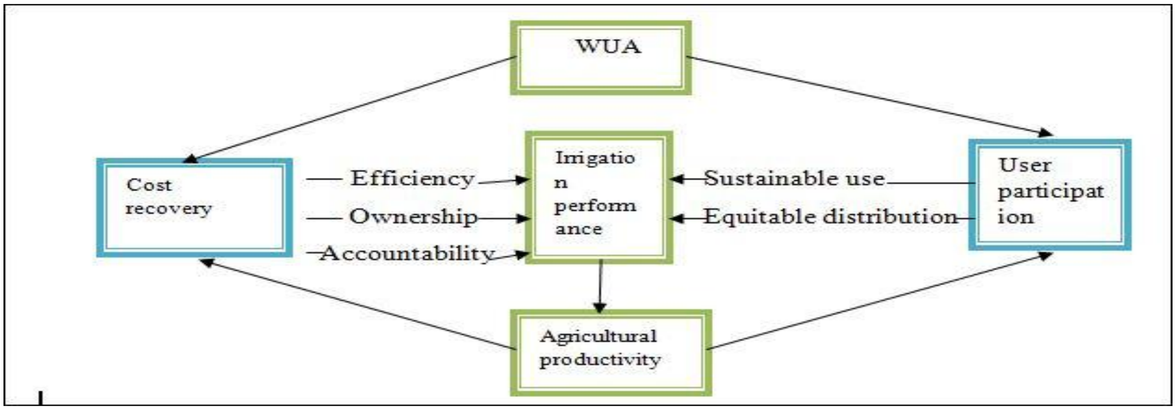

Figure 2.1: Theoretical framework of WUAs (Aarnoudse *et al*.,2018)

1.2. Factors influencing WUA performance

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

1.3. Strengthen water user association

Policy makers and donor agencies have tried five main channels to strengthen conventional WUAs: i.WUA policy and legal instruments ii.WUA bylaws iii. Contracts and formal agreements with WUAs iv. Training of WUA members v. Introducing monitoring and evaluation (Aarnaoudse *et al*. ,2018).

I.WUA policy and legal instruments

Donors and policy makers turned to the development of national-level legal instruments to regulate WUA operations to make them more effective. In some cases, donor agencies push national governments to put forward desirable WUA regulations that enforce the 'norms' in conventional WUAs, including cost recovery and user participation based on principles of equity.

II.WUA bylaws

Bylaws are "the constitutional rules of each WUA" (Lemperiere *et al*., 2014: 21), sometimes referred to as the 'internal code' or 'constitution'(Vandersypen *et al*., 2007; Zuka, 2016). Important aspects included in bylaws are structure and mandate of the WUA board, rights and duties of WUA members, procedures for calling meetings and setting irrigation fees (Lemperiere *et al*.,2014). Generally, water users themselves are supposed to set WUA bylaws to ensure they are fit to purpose.

III. Contracts and formal agreements with WUAs

A more direct way to enforce requirements upon WUAs is the enactment of contracts or agreements with WUAs. These can be transfer agreements between the WUA and the government and/or donor agency defining the rights and duties of each party. The agreement may include cuts in financial support if requirements are not met.

IV. Training of WUA members

Another approach to improve WUAs is through training. Here, the focus is not so much on formalizing institutions, but on building internal capacities with regard to the technical, financial and managerial skills considered necessary to manage a WUA and take over O & M tasks.

V. Monitoring and evaluation

Development banks and agencies have sought to introduce or strengthen monitoring and evaluation within and on WUAs toward ensuring effectiveness. Monitoring and evaluation of a WUA income and expenditure, as well as water use and levels could contribute to the transparency of its financial governance and improved service delivery. However, monitoring data on the availability and distribution of water is often lacking at WUA level, which can undermine the ability of WUAs to control water use and impose sanctions when users do not respect irrigation turns or any other operational rule.

3. MATERIAL AND METHODS

3.1. Description of the Study Area

The study was conducted at Assosa Woreda, Benishangul gumuz Regional state, found in the Upper Blue Nile (Abay) River Basin, Ethiopia. It is located at a distance of about 665 km to the North West of Addis Ababa. It is located at $9^{0}40'0''$ N -$10^{0}23'20''$ N latitude and $34^{0}8'20''$ E- $34^{0}51'40''$ E longitude at about 1560 meters above sea level (m.a.s.l).

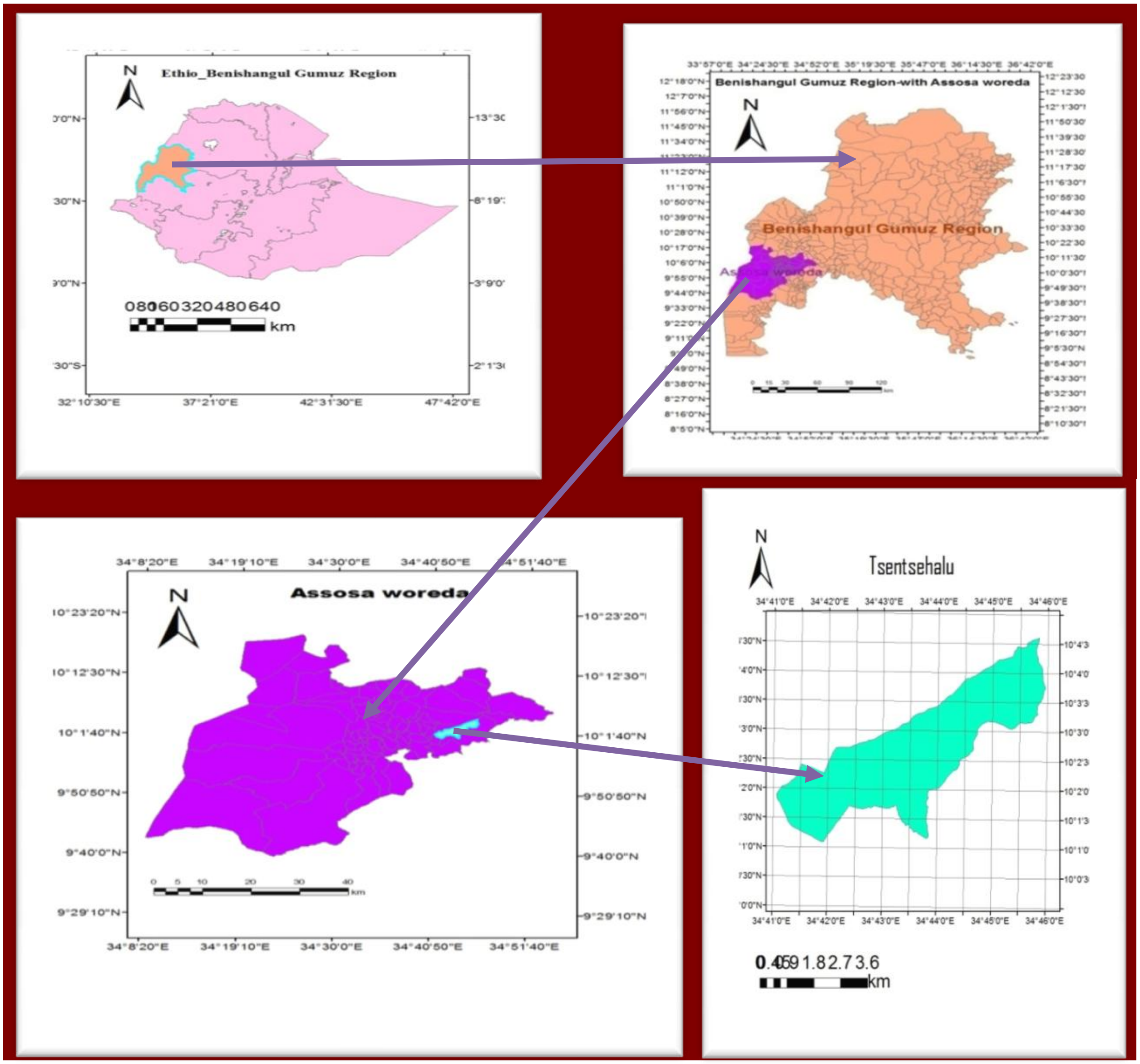

Figure 3.1: Location map of the study area

The agro-climatic zone of the area is hot to warm moist lowland plain with unimodal rainfall distribution pattern. The rainy season starts at the end of April and lasts at the end of October with maximum rainfall in June, July, August and September. The mean annual minimum and maximum temperatures of the area for the same years were 14.63 and 28.61^{O}C, respectively (Source: Assosa Woreda Agricultural Office).

3.1.1. Golda small scale irrigation scheme

It is located at a distance of about 18km from Assosa to the west direction, the capital city of the region. Golda catchment lies between Latitude 9^{0}50'25.77" and 9^{0}56'58.2"N and Longitude 34^{0}33'4.7"and 34^{0}38'35.5"E. It has an area of about 53km^{2}. It is characterized by mountainous land in its southern boundary and the rest of the area up to the point of the diversion is flat land with smaller areas bordering the river having moderate to steep slopes. The Golda river descends to 160m in 10 kilometers with an average slope of 0.016m/m. Cultivation is limited to the areas adjacent to the river in Gambashir/Tsentsehalu Kebele. Other areas between the foot of the mountains and the kebele[1] are covered with grass and bamboo forests. The mountains are also covered with tree forests. No flow gauging station had been installed on the Golda river to- date to measure the flows (Source: Design Document).

The area is characterized by rainfall that may last up to six months in most cases. Farmers of the area mainly rely on rain fed subsistent agricultural activities. Sorghum, maize, sesame and groundnut are the main crops of the area and also in irrigation maize, onion, tomato, potato, pepper and cabbage.

The Government of Federal Democratic Republic of Ethiopia (FDRE) has prepared the Growth and Transformational Plan (GTP) or Millennium Development Goal (MDG) as a solution to enhance development of the country by increasing agricultural productivity. Hence, Benishagul Gumuz Regional Government committed to construct Golda small scale irrigation that has about 62ha of irrigable land in order to reduce poverty and to increase productivity at Household, Regional and National level. However, despite the fact that irrigation farming is highly beneficial to enhance productivity not all the farmers of the Kebele have farmland within the command area of Golda irrigation scheme (Source: Design Document). Irrigation development is the first and the most important solution to address Growth and Transformational Plan (GTP). Golda

[1]The lowest government administrative unit

small scale irrigation scheme would have enhanced productivity and decrease the down time of the beneficiary farmers as irrigation farming is labor intensive. Furthermore, the project was creating job opportunity for the population residing in and around the project during construction and after construction. It was with this understanding that the Benishangul Gumuz Agriculture and Rural Development Bureau signed contract agreement with Metaferia Consulting Engineers for the study of Golda small scale Irrigation scheme Design (Source: Design Document).

Figure 2.2: Diversion Weir of Golda irrigation scheme

3.2. Data Collection and Analyses

3.2.1. Method of data collection

In this study both quantitative and qualitative approach were applied. The data was collected from primary and secondary sources.

3.2.2.1. Secondary data collection

I. For evaluation of water delivery performance indicators: Secondary data was collected from different sources. The data like long time average climatic data of mean monthly minimum and maximum temperature, rain fall, relative humidity, wind speed and sunshine hours were collected from Assosa meteorological station and estimated from nearby meteorological stations using New_LocClim[2] 1.10 soft ware. Additional secondary data like (Kc, maximum rooting depth, length of growing season and MAD), were collected from reports and research publications.

[2]It is local climate estimator soft ware

II. For evaluation of on field water management performance: The following data like, total command area, irrigable area, irrigated area, crop yield, cost of irrigation scheme, etc.were collected from Woreda and Zonal Agricultural Offices, Design Documents and from respective stakeholders. The climatic data was also used for this specific objective.

3.2.1.2. Primary data collection

primary data was collected through field measurements, through formal and informal survey approaches. Field observation and house hold surveys were practiced for information gathering and analysis.

I. To evaluate the water delivery performance of Golda small scale irrigation scheme using performance indices: The following primary data were collected:- Field observations were taken to assess both the structural integrity of system components and their fitness to convey flows.

Discharge measurement: It was a relevant data for irrigation scheme performance evaluation activities, computation of conveyance efficiency and losses. There are different methods to measure the flow of water in the canals. For this study the flow rate was determined by floating method and using partial flume. To determine the flow rate at farm inlets; measurements was taken by Partial flumes from sampled farmers. Those farmers were selected based on their willingness.

Total water supply, irrigation supply, Irrigation demand, Crop water demand, water received at the inlet of the selected fields, water released from the project head work and average depth of water applied were calculated**.**

II. For evaluation of on field water management performance of Golda small scale irrigation scheme, the following primary data were collected:

- ✓ Soil samples using auger at 30 cm depth intervals from the surface up to maximum rooting depth of the crop (0-30, 30-60, 60-90 & 90-120cm) for the determination of BD, texture, FC, PWP, and soil moisture content, organic matter content, soil pH, total nitrogen and available phosphorus.
- ✓ Soil moisture before and after irrigation were determined by gravimetric estimation

- ✓ Infiltration characteristics of the soil was determined using double ring inifiltro meter. The maximum infiltration rate was used for crop water requirement, irrigation water requirement and irrigation scheduling calculation in the CROP WAT[3] 8.0 soft ware.
- ✓ Observations were made how farmers control and manage irrigation water during irrigation events.

III. In order to evaluate organizational setups and performances for irrigation water management and scheme maintenance: For this assessment house hold survey was held. **House hold survey**: Issues related to water management experience, their felling due to the construction of the irrigation scheme, maintenance of the scheme, canal cleaning, organizations, community level problems and experiences, etc. were collected through questionnaire. Before conducting the interviewee the questionnaire was prepared and tested.

Sampling Technique: The total beneficiaries in the selected command area were 210. The representative sample size was determined using Yamane (1967) simplified formula (3.1). Finally, the calculated samples were used for house hold survey.

$$n = \frac{N}{1+N(e^2)} \quad \text{--} (3.1)$$

Where:

n: sample size

N: population size

e: level of precision

The calculation was carried out using 95% confidence interval, 10% precision level and 50% degree of variability (P).

Accordingly:

$$n = \frac{210}{1+210(0.1^2)}$$

n =68

Simple random sampling technique has been used to select male and female respondents from each canal reaches.

[3]It is crop water requirement soft ware

3.3. Data Analyses

3.3.1.water delivery indicators analysis

3.3.1.1. Discharge measurement

The aim of good irrigation management is to obtain a correct flow division within the canal network and over the fields. This means that discharges in canals should meet the demand for water from the farms. A poor flow division may result in discharges being too high in some canals and too low in others, and could lead to water disputes between farmers. To achieve sufficient and equitable delivery of water to the fields it is useful to know the discharge in the canal.

I. Canal discharge measurement

The discharge in the canal was measured with floating method. The method consists of estimating the average flow velocity and measuring the area of the cross-section, called the 'wetted cross-section'. The discharge was calculated by continuity equation 3.2.

$Q = V * A$--(3.2)

where: Q: the discharge (m^3/s)

V: the average flow velocity (m/s)

A: the area (m^2) of the wetted cross-section.

Average flow velocity

To estimate the average flow velocity, the flow velocity of the water at the surface , the surface velocity, Vs was first determined. The surface velocity was determined by measuring the time it takes for a floating object along the canal. The floating object was placed in the centre of a canal and the time measurement was repeated three times to avoid mistakes. The stretch of canal used for measurement should be straight and uniform, in order to avoid changes in the velocity and in the area of the cross-section, because any such variation reduces the accuracy of the velocity estimation.

To determine the velocity of surface water of the channel, the length of trail section was divided by the average time taken by the float cross it. Since the velocity of the float on the surface of the water was greater than the average velocity of the stream, it was necessary to correct the measurement by multiplying by a constant factor (velocity correction factor) which was usually assumed to be 0.85 (Harrelson, 1994). To obtain the rate of flow, this average velocity (measured velocity * correction factor) was multiplied by the average cross-sectional area of the stream.

To compute the surface velocity, Vs the selected length , L was divided by the travel time, t:

$Vs = \frac{L}{t}$---(3.3)

where: Vs: the surface velocity (m/s)

L: the distance in meters between selected points and

t: the travel time in seconds between selected points

The surface velocity must be reduced in order to obtain the average velocity, because surface water flows faster than subsurface water.

$V = 0.85 * Vs$--(3.4)

where: V: the average flow velocity (m/s); Vs: the surface velocity (m/s) found from equation (3.3).

Area of the wetted cross-section

For measuring the flow with the floating method, the area of the wetted cross-section (A) was determined for a selected straight and uniform portion of the canal. The area was calculated from measurements of the surface water width and the water depth using equation 3.5.

$A = w1 * h1$---(3.5)

where: A: area of wetted cross-section (m^2)

w1: surface water width (m)

h1: water depth (m)

The area of the cross-section was measured three times to get the average area.

Flow estimation procedure

The following procedures were applied for measuring the discharge using a floating method.

1. Select a straight section of the canal at 10 meters long.
2. Place two stakes, one each side, at the upstream end of the selected portion of the canal. They should be perpendicular to the centerline of the canal. These correspond to point A
3. Measure 10 meters or more along the canal.
4. Place two stakes at the downstream end of the selected section of the canal, also perpendicular to the centerline of the canal. These correspond to point B
5. Place the floating object on the centre line of the canal at least 5 m upstream of point A, and start the stopwatch when the object reaches point A.
6. Stop the stopwatch when the floating object reaches point B, and record the time.
7. Repeat steps 5 and 6 at least three times in order to determine the average time necessary for the floating object to travel from point A to point B.

8. Measure the following in the selected canal section the surface water width and the water depth

9. Calculate the surface velocity and then the average flow velocity using the previous equations 3.3 and 3.4 respectively.

10. Calculate the wetted area of the cross-section using equation 3.5

11. Calculate the discharge in the canal using equation 3.2

Determination of the losses

The conveyance loss was measured using the inflow-outflow method, which involves measurement of the rate at which water flows in to a water course test section and the rate at which water flows out of it. The reading was taken when the flow became steady. Readings were recorded simultaneously three times. By measuring the section length under the loss of water per 100m was calculated by the following formula (Michael, 1986).

$Q_l = (\frac{Q_{i-}Q_o}{L}) * 100$--(3.6)

Where,

Ql : water loss rate in channel (l/s/100m)

Qo : quantity of water delivered by a conveyance system (outlet) (l/s)

Qi : quantity of water delivered to a conveyance system (inflow) (l/s)

L : length of channel under test (m)

II. Field discharge measurement

The discharge which was applied to the field was measured by standardized size 3-inch parshall flume. To determine the amount of water applied by the irrigators to the field, during an irrigation event, three inch partial flume was installed at the entrance of test field. Frequent readings were taken when the farmers irrigate the test field. Irrigation was continuing until the farmers thought that enough amount of water is applied to the field. When the irrigator completed irrigating the test field, the average depth of irrigation water passing through the flume and the respective time were recorded for the sizes of test field being irrigated. The discharge was computed using equation 3.7, and the depth of water applied was computed from discharge, cut-off time and area irrigated. The time of cut-off was the time farmer's decide that enough water would have been applied to their fields. According to Walker and Skoerboe (1987), discharge was computed as:

$\mathrm{Qf} = \mathrm{Cf} * \mathrm{W} * \mathrm{hu}^{\mathrm{nf}}$--(3.7)

Where: Qf: discharge for free flow condition

W: throat width , Cf: free flow coefficient, nf: exponents for free condition and hu: upstream heads of parshall flume (m).The values of W, Cf and nf are indicated in the (appendix 3.1) and the depth of water applied was computed from discharge, cut-off time and area irrigated.

Figure 3.3: Determination of discharge, cross section and cross drainage structure

3.3.1.2. Conveyance efficiency

The water conveyance efficiency and water losses main and tertiary canals were estimated by measuring inflow and outflow for the selected canal reaches. The average values of inflow and out flows for all measurements for each of the selected canals were used for the estimation of water conveyance losses and water conveyance efficiency using (Michael, 1986), equation 3.8.

$$\mathbf{Ec} = \frac{\mathbf{Qinflow}}{\mathbf{Qoutflow}} * \mathbf{100} \text{---} (3.8)$$

3.3.1.3. Relative water supply

As Molden *et al*.(1998) stated those relative water supply and relative irrigation supply were calculated using equations 3.9 and 3.10 respectively.

$$\mathrm{RW}(\mathrm{m}^3) = \frac{\textbf{Total water supply}}{\textbf{crop water demand}} \text{--} (3.9)$$

Where, total water supply (m3) is diverted water for irrigation plus rainfall, crop water demand (m3) is the potential crop evapotranspiration (ETp), or the real evapotranspiration (ETc) when full crop water requirement is satisfied. Crop water demand was calculated as the following below: Crop water demand=CWR maize*(Area of maize/Total area)+CWR onion*(Area of onion/Total area)+[CWR tomato*(Area of tomato/Total area)+CWR potato*(Area of potato/Total area)+ CWR pepper*(Area of pepper/Total area)+CWR cabbage*(Area of cabbage/Total area)+CWR carrot*(Area of carrot/Total area)+CWR banana*Area of banana/Total area)+CWR chat*(Area of chat/Total area)].The same procedure was applied for effective rain fall and irrigation demand.

3.3.1.4. Relative irrigation supply

RIS (m^3)=$\frac{\text{Irrigation supply}}{\text{Irrigation demand}}$---(3.10)

Where, irrigation supply (m^3) is surface diversions for irrigation, irrigation demand (m^3) is the crop ET minus effective rainfall. Net crop water requirement and irrigation requirement calculated by CROPWAT 8.0 model (FAO, 2009). The reference evapotranspiration (ETo) is calculated on a monthly basis using the FAO Penman-Monteith (FAO, 2009).

3.3.2. On field water management performance

For this type of evaluation soil data, reference evapotranspiration, rainfall, crop water and irrigation water requirement, irrigation scheduling , internal and external performance indicators were analyzed.

3.3.2.1. Soil data analysis

I. Soil texture: The particle size distributions in the soil profiles were determined using the hydrometric method as indicated by Staney and Bernard (1992). Composite soil samples in the head, middle and tail reach of the study area were taken using Auger at 0-30cm, 30-60cm, 60-90cm and 90-120 cm soil depth. The soil samples were first air dried and grinded using pestle and mortar, and then sieved using 50 and 250 micron size sieves. After that 25 gm of soil and 50 ml dispersing agent (40 gm sodium Hexametaphosphate, $Napo_3$ and 10 gm of Sodiumcarbonate, Na_2co_3) was mixed in distilled water in 500 ml flask. The soil and solution were then transferred to mechanical stirrer and shake for 5 minutes. The dispersed soil suspension was then transferred to hydrometer jar and the volume in the hydrometer was adjusted to 500 ml by adding distilled water. The readings were taken after 40 seconds and after 2 hours.

The hydrometer reading results were corrected to a 20^0C. For temperature readings above 20^0C correction values are added to the hydrometer reading, but for temperature readings below 20^0C correction values are subtracted to the hydrometer reading ISRIC (2000). This is because, for example for the 40 second readings when the temperature is above 20^0C the movement of particles are high. So, some sand particles may suspend in addition to the clay and silt particles.

However, if temperature value is less than 20^0C the kinetic energy is low and all clay and silt particles may not be suspended. The other correction factor is salt correction. A constant value of 2 is subtracted from every hydrometer reading to correct the effect of salt on the hydrometer results. The corresponding temperature correction values are presented in (Table 3.1). The results were calculated according to the national soil research center EARO (2000) and the formula as given by equations 3.11 to 3.13.

$\%\,\text{sand} = 100 - [(\text{d}1 \pm \text{C}1 - 2) * \frac{100}{25}$--(3.11)

$\%\,\text{clay} = (\text{d}2 \pm \text{C}2 - 2)\ \frac{100}{25}$---(3.12)

$\%\,\text{silt} = 100 - (\%\,\text{sand} + \%\text{clay})$---(3.13)

Where:

d1, d2 : Hydrometer readings at 40 second and 2 hours respectively

C1, C2 : Temperature corrections at 40 second and 2 hours respectively

$\frac{100}{25}$: to convert sample weight to 100

2 : Salt correction factor

Then, the soil textural class was determined using the USDA textural triangle method for the percent soil fraction as determined from the hydrometric analysis.

Table 3.1: Temperature correction values of Hydrometer readings

Temperature (^{O}C)	15	16	17	18	19	20	21	22	23	24	25
Correction value	-2	-1.5	-1	-1	-0.5	0	0.5	1	1	1.5	1.5

Figure 3.4: Soil textural class determination /Hydrometer reading in the laboratory

II. Bulk density: Bulk density of the soil profile was determined using undisturbed soil samples at 0 - 30 cm depth interval collected by using 4.8cm internal diameter and 4cm height, 4.4cm internal diameter and 4cm height and 4.6cm internal diameter and 4cm height core sampler from head, mid and tail reaches respectively. The analysis was undertaken in the Assosa Agricultural Research Soil Laboratory. The bulk density was determined using (Jaiswal, 2003), equation 3.14.

$$BD = \frac{Ws}{Vc} \text{--(3.14)}$$

Where:

BD : soil bulk-density (g/ cm^3)

Ws : mass of dry soil (g) and

Vc: volume of soil in the core (cm^3) and $Vc = A * h$---(3.15)

Where: A: area of the core (cm^3)

h: height of the core (cm)

The area of the core was calculated as equation 3.16, because the core was circular.

$$A = \pi \frac{d^2}{4} \text{--(3.16)}$$

d: internal diameter of the core (cm)

III. Soil pH: Soil pH was determined for the identification of whether the soil has acidity or salinity problem. It was measured in 1:2.5/soil: water mixture by using pH meter. Distilled water was used as a liquid in the mixture. Ten gram air dried < 2 mm soil was weighed into 100 ml beakers and 10 ml distilled water was added to 1:2.5/ soil: water suspension and transferred to an automatic stirrer, to be stirred for 30 minutes and pH on the upper part of the suspension was measured.

IV. Soil field capacity and permanent wilting point: Field capacity and permanent wilting point of the soil were analyzed through pressure plate apparatus in the laboratory. Soil samples were saturated for one day and a pressure of 1/3 bar (for field capacity) and 15 bars (for permanent wilting point) were exerted until no further change in soil moisture content was observed. After getting soil moisture values, available water holding capacity of the soil was calculated. The total available water (TAW) for crop use in the root zone was calculated using Allen *et al*.(1998) equation 3.17 & 3.18.

The total available water in percent based:

$$TAW(\%) = \Sigma(FC\% - PWP\%) \text{---(3.17)}$$

Where: TAW(%): total available water in percent

FC%: soil moisture at field capacity in percent

PWP%: soil moisture at permanent wilting point in percent

The total available water content in volumetric based:

$$TAW = 1000\,\Sigma(\theta FC - \theta PWP) * BD * Zr \text{----------}(3.18)$$

Where: TAW: volumetric total available water in the root zone (mm/m)

FC: volumetric moisture content at field capacity (m^3/m^3) and

PWP: volumetric moisture content at permanent wilting point (m^3/m^3).

BD: bulk density(gm/cm^3)

Zr: root zone depth (m)

V. Soil infiltration rate: The infiltration rate of the soil was determined using double ring infiltrometer. The inner and outer rings have 30cm and 60cm diameter respectively. Water was added to the soil with certain interval of time. The cumulative depth of infiltration and the time elapsed was recorded carefully. Measurements were taken in the internal ring, but the purpose of the external ring was protecting the lateral movement of the water through the soil. After a long time, the infiltration rate of the soil reached nearly constant and this was termed as basic infiltration rate. The constant value of the basic infiltration rate expressed in cm per hour obtained after a long time was used as an input data for the CROPWAT8.0 Model that was useful for the determination of crop water and irrigation water requirements.

Figure 3.5: Infiltration test of the soil at field

VI. Soil moisture determination: Soil samples were taken before and at two days after irrigation. Samples for soil moisture determination were taken by auger at the head, center and tail end of the furrows of the selected head, mid and tail reach of farms. Samples were collected at depths of 0 – 30, 30-60, 60-90 and 90-120cm, and were analyzed in the laboratory using gravimetric method with a view to determine soil moisture content for water stored in the soil during each irrigation event. The wet soil samples were placed in containers of known weights and were weighed to find the total weights. The container with the sample was then placed in an oven, set and kept at a temperature of $105^{O}C$ and dried for 24 hrs. The sample and the container were then weighed. The difference between the weights before oven/heating and after oven/heating gave the moisture content/gravimetric water content of the soil sample. Its gravimetric water content was then determined using Jaiswal (2003), equation 3.19.

$$\theta dw = \frac{Wws - Wds}{Wds} \text{--} (3.19)$$

where:

Wws: weight of wet soil (g)

θdw: water content expressed on weight basis in (%)

Wds: weight of dry soil (g)

and the volumetric water content was calculated from the gravimetric water content using the following expression

$$\theta V = \frac{\rho b}{\rho w} * \theta dw * 100 \text{---} (3.20)$$

Where:

θv: volumetric moisture content in (%) ρb : soil bulk density(g/cm^3) and ρw: water density g/cm^3 (1g/cm^3)

Figure 3.6: Soil moisture determination using oven dry method

VII. Organic matter content: Applying organic matter is one of the best methods in achieving and maintaining a fertile soil for this improves the cohesiveness of the soil, increases its water retention capacity and promotes a stable aggregate structure (Morgan,1986).Titration method, which is oxidation under standardized condition with potassium dichromate in sulpheric acid was followed for organic carbon determination. Finally, conversion of organic carbon to organic matter by multiplying percentage organic carbon by 1.724 to obtain organic matter content.

VIII. Total Nitrogen and available Phosphorus: Sadras *et al*.(no date) suggested that nutrient availability, particularly nitrogen and phosphorus, are critical to high yield and water productivity. Total Nitrogen was determined by Kjeldhal method in the laboratory. The procedure was based on the principle that the organic matter was oxidized by treating soil with concentrated sulfuric acid, nitrogen in the organic nitrogenous compounds being converted into ammonium sulfate during the oxidation. NH_4^+ ions in the soil were trapped by the acids which were liberated by distilling with NaOH. The liberated NH_4^+ is absorbed in boric acid and back titrated with standard H_2SO_4.

Phosphorous is known as the master key to agriculture because lack of available P in soil limited the growth of both cultivated and uncultivated plant (Foth and Ellis,1997).To correct this deficiency farmers are advised to add P to their soil in the form of manure or fertilizer. Available phosphorus was determined by Olsen method which is sodium bicarbonate method.

3.3.2.2. Determination of reference evapotranspiration (ETo)

Reference evapotranspiration was computed using CROPWAT 8.0 model as a measure of evaporative demand of the atmosphere. It has been estimated with the FAO Penman-Monteith equation (FAO, 2009) using the ETo calculator program, included monthly meteorological recordings data was collected including the geographical location of the study area using the expression:

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma(900/T + 273)u2(es - ea)}{\Delta + \gamma(1 + 0.34u2)} \quad \text{------(3.21)}$$

Where:

ETo: reference evapotranspiration (mm/day)

Rn: net radiation at the crop surface (MJ/m^2/day)

G: soil heat flux density (MJ/m^2/day)

T: mean daily air temperature at 2 m height (^{o}C)

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)

γ: psychrometric constant (kPa/^{o}C)

3.3.2.3. Rainfall data analysis

I. Rainfall data: The precipitation data required for CROPWAT 8.0 was monthly rainfall, commonly available from Assosa climatic station. Long term rainfall records were collected.

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

3.3.2.4. Determination of crop water and irrigation water requirement

The crop water requirement of different crops in the study area was calculated using CROPWAT 8.0 model which is familiar and easy to manipulate. CROPWAT 8.0 has been compute crop water requirement by feeding the computed monthly ETo values together with the necessary crop, rainfall and soil data. The water requirement of crops was calculated by taking into consideration the growth periods (initial, development, mid season and late season) using CROPWAT 8.0 model. Crop water requirement or ETc can be calculated as:

$$ETc = Kc \times ETo \quad (3.22)$$

Where:

ETc: crop evapotranspiration/crop water requirement (mm/day),

Kc: crop coefficient, which is a function of crop type and stage of growth

ETo: reference evapotranspiration (mm/day)

The crop coefficient values for respective growth stages, length of growth stages, and soil moisture depletion level and root depth of each crop were collected from Allen *et al.*(1998).

The net irrigation water requirement (IRn) was computed after estimation of effective rainfall by the CROPWAT 8.0 model.

$$IR_n = ETc - P_{eff} \quad (3.23)$$

Where:

IRn: net irrigation water requirement (mm)

Peff: effective rainfall (mm)

3.3.2.5. Irrigation scheduling

Irrigation scheduling was worked out using CROPWAT 8.0 model by adjusting the depth to a constant value for no yield reduction and minimum water loss. To calculate irrigation interval, first readily available water was determined from total available water and management allowable depletion. The total available water was calculated using previous equation 3.17 and the management allowable deficit is the amount of water stored in the soil that is readily available to the plant. It was calculated as Allen *et al*.(1998), equation 3.24 & 3.25.

$$RAW = TAW * P \quad (3.24)$$

Where:

RAW: readily available water (mm)

P: water depletion fraction/management allowable depletion (%).

Then the irrigation interval was calculated as:

$$I = \frac{RAW}{ETc} \quad (3.25)$$

Where:

I: irrigation interval (days)

3.3.2.6. Internal indicators

For evaluation of field water management performance, the following internal performance indicators were used. For the analysis of irrigation efficiencies, composite soil samples at 0-30, 30-60, 60-90 and 90-120cm depth in head, middle and tail canal reaches were taken before and after each irrigation event. Then soil moisture contents of the sampled soil were determined gravimetrically.

I. Water application efficiency: Field data collection was conducted to determine field application efficiency at the users' field by measuring the head in the head ditch, counting the number and recording the running time of the partial flume. The average soil moistures in the effective root zone on selected points were taken. According to Merriam *et al*.(1983), application efficiency was calculated as:

$$\mathrm{Ea} = \frac{\text{Average depth of water stored in the root zone (Ws)}}{\text{Average depth of water applied (Wf)}} * 100 \text{--(3.26)}$$

II. Water storage efficiency: It was calculated according to (Michael, 2008): equation 3.27

$$\mathrm{Es} = \frac{\text{water stored in the root zone of the crop (Ws)}}{\text{Water needed in the root zone prior to irrigation (Wn)}} * 100 \text{--(3.27)}$$

The water needed in the root zone prior to irrigation was computed using (Michael, 2008) equation as:

$$\mathrm{Wn} = \sum_{i=1}^{n} \left(\frac{M_{fci} - M_{bi}}{100}\right) * A_i * D_i \text{--(3.28)}$$

Where:

Mfci: field capacity moisture content in the i^{th} layer of the soil (%)

Mbi: moisture content before irrigation in the i^{th} layer of soil (%)

Ai: bulk density of the soil in the i^{th} layer

Di: depth of the soil layer within the root zone cm, and

n: number of soil layers in the root zone D

III. Water distribution uniformity : This is important to evaluate the distribution of water on field. Merriam *et al*.(1983), distriution uniformity was calculated as:

$$DU = \frac{\text{Average low quarter depth of water infiltrate}}{\text{Average depth of water infiltrated}} \text{---(3.29)}$$

The depth of stored water at particular soil layer was calculated using the equation below:

$$\mathrm{Z} = \left(\frac{M_{ai} - M_{bi}}{100}\right) A_i * D_i \text{---(3.30)}$$

Where:

Mai: moisture content of the i^{th} layer of the soil after irrigation weight basis, %

Mbi: moisture content of the i^{th} layer of soil before irrigation weight basis, %

The total depth of water stored at the place of soil sampling from Z_1 to Z_9 was calculated as:

$Z_1=Z_{1(0\text{-}30)}+Z_{1(30\text{-}60)}+Z_{1(60\text{-}90)}+Z_{1(90\text{-}120)}$---(3.31a)

$Z_2=Z_{2(0\text{-}30)}+Z_{2(30\text{-}60)}+Z_{2(60\text{-}90)}+Z_{2(90\text{-}120)}$--(3.31b) to

$Z_9=Z_{9(0\text{-}30)}+Z_{9(30\text{-}60)}+Z_{9(60\text{-}90)}+Z_{9(90\text{-}120)}$---(3.31c)

Then, DU was calculated by using equation 3.29

V. Deep percolation ratio : Since the furrow which practiced by farmers was closed-end and the evaporation from the soil was only a short period after irrigation, so that both parameters were neglected. The only loss of irrigation water beyond the root zone was through deep percolation. Deep percolation ratio could be calculated indirectly from values of application efficiency and runoff ratio as given by Feyen and Dawit(1999).

$\mathrm{DPR} = 100 - \mathrm{Ea} - \mathrm{RR}$---(3.34)

Where: RR: runoff ratio

V. Overall/Project efficiency : According to FAO (2002) the project or overall efficiency of the scheme was calculated as the product of conveyance and application efficiency.

$\mathrm{Ep} = \mathrm{Ec} \times \mathrm{Ea}$ --(3.35)

3.3.2.7. External indicators

I. Agricultural output indicators /Land and water productivity

A. Land productivity indicators: Land productivity quantifies change in crop yield or value per unit area (Bos *et al*.,2005). The data regarding to production value in local price, irrigated crop area and command area was found from Assosa Woreda Agricultural Office and irrigation users during house hold survey. These indicators were computed using Molden *et al.(*1998) equation 3.36 & 3.37.

Output per unit irrigated area ($/ha) = $\frac{\text{Production}}{\text{Irrigated crop area}}$---(3.36)

Output per unit command ($/ha)= $\frac{\text{Production}}{\text{Commmand area}}$.---(3.37)

B. Water productivity indicators: Water productivity quantifies change in crop yield or value per m^3 water supplied (Bos *et al.*,2005). The following two water productivity indicators were calculated based on Molden *et al*.(1998) equation 3.38 & 3.39.

Output per unit irrigation supplied ($/m^3) = $\frac{\text{Production}}{\text{Diverted irrigation supply}}$------------------------------(3.38)

Output per unit water consumed ($/m^3) = $\frac{\text{Production}}{\text{Volume of water consumed by ET}}$-------------------------(3.39)

Where:

Production: the output of the irrigated area in terms of gross or net value of production measured at local or world prices.

Irrigated cropped area: the sum of the areas under crops during the time period of analysis

Command area: the nominal or design area to be irrigated

Diverted irrigation supply: the volume of surface irrigation water diverted to the command area and Volume of water consumed by ET: the actual evapotranspiration of crops

IV. Physical indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons.

A. Irrigation ratio: According to Bos *et al*.(1994), it is the ratio of currently irrigated area to the command area.

$$\mathrm{IR} = \frac{\text{irrigated area}}{\text{command irrigable area}} \text{--(3.40)}$$

Where:

Irrigated crop area (ha): the portion of the actual irrigated land in any given irrigation season,

Command area (ha): the potential scheme command area

B. Sustainability of irrigated area: According to Molden *et al.(*1998), it is the ratio of currently irrigable area to the initial irrigated area.

$$\mathrm{SIA} = \frac{\text{current irrigable area (ha)}}{\text{Initial irrigated area}} \text{--(3.41)}$$

Where:

Current irrigable area: the area currently irrigated (ha)

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

V. Financial indicator

A. Gross return on investment: It was calculated according to Molden *et al*.(1998).

$$\mathrm{GRI}(\%) = \frac{\text{Production}}{\text{Cost of irrgation infrastructure}} \text{---(3.42)}$$

Where:

Cost of irrigation infrastructure: considers the cost of the irrigation water delivery system referenced to the same year as the production.

The cost of irrigation infrastructure was estimated as present net worth (PNW), through the average interest rate of the service years.

$PNW=p*(1+i)^n$

where:

p: initial investment cost

i: average interest rate in the service years(%)

n: number of service years

3.3.3. Organizational setup and performance for irrigation water management and scheme maintenance

Sample questionnaires were prepared accordingly to answer organizational setup and performance for irrigation water management and scheme maintenance and the data were collected from 68 irrigation users then the collected data were analyzed with SPSS 20.software and interpreted using descriptive statistics.

Figure 3.7: House hold survey in the study area

4. RESULTS AND DISSCUSSION

4.1.Water Delivery Indicators

Transporting the diverted water to the location of use, i.e.to the cropped field, is the main purpose of water delivery systems. In the course of this transport there are different losses that reduce the amount of water reached to the farm. Water delivery indicators were calculated based on equation 3.8, 3.9 and 3.10, respectively.

4.1.1. Conveyance efficiency and losses

The irrigation scheme had been only main canal and tertiary canals so that conveyance efficiency and losses were determined for main and tertiary canals. The calculated main and tertiary canal efficiencies were 78% and 68% respectively as indicated in (Table 4.1).The conveyance efficiency of the scheme would be the product of main and tertiary canals which was 53%. Nearly similar result was reported by Tesfaye (2018) at Wosha small scale irrigation scheme. The value was below FAO (1989) recommended values which greater than 2000 meters canal length earthen canals in clay soil of conveyance efficiency should be 80%. As a result the conveyance efficiency of Golda irrigation scheme was poor.

The major causes of high water loss or low conveyance efficiency was seepage, evaporation and malfunctioning control gates. This inefficient conveyance affected the equity of water distribution throughout the systems; particularly the tail users did not get their equitable share within the required time.

Table 4.1: Calculated conveyance efficiencies and losses

Canals	Conveyance efficiency (%)	Conveyance losses(l/s/m)
Main canal	78	0.76
Territory canal	68	0.81
Average conveyance efficiency of the scheme	53	

4.1.2.Relative water supply

The calculated value of relative water supply was 1.6 as indicated in (Table 4.2).Similar result was reported by Shinkut (2015), at Shina-Hamusit small scale irrigation scheme which was 1.55. As the result shows, it was greater than one which means the total supplied water was above sufficient to meet crop demand or excess water was used beyond crop demands as Perez *et al.* (2005), categorized relative water supply values ranging from 0.9 to 1.2 as adequate, and from 1.2 to 1.8 as, and values from 1.8 to 2.5 as very excessive. Similarly, the value less than one does not mean insufficient water supply rather; it mean that farmers can apply deficit irrigation. Greater than unity of relative water supply was also reported by Toli (2018), at Bobe and Laku small scale irrigation schemes.

4.1.3. Relative irrigation supply

The computed value of relative irrigation supply was 1.2 which means that the diverted irrigation supply was sufficient for irrigation demand of the crop. The higher value of irrigation supply was due to absence of irrigation water fees. Similar result was obtain by Dejen *et al*.(2012), at Wedecha scheme (Godino sub-system). It is better to have a relative irrigation supply near one than a higher value. The lower value of RIS obtained due to the contribution of effective rainfall for crop water demand during the irrigation seasons (Molden *et al*.,1998).

Table 2.2: Parameters and calculated water delivery indicators

Irrigation demand m^3	Crop water requirement m^3	Effective rainfall m^3	Irrigation supply m^3	RIS	RWS
259,003	317,054.5	58,051.5	4,403,051	1.2	1.6

4.2. On Field Water Management Indicators

4.2.1. Soil data analysis results

4.2.1.1. Soil textural class, bulk density, pH and nutrient contents

The sampled properties of the soil (bulk density and texture) was analyzed and the results were indicated in (Table 4.3). The bulk density at head, middle and tail reaches of the canal were 1.11, 1.12 and 1.25 gm/cm^3 respectively. In the tail reach of the canal higher values of bulk density was recorded which indicates the soil was highly compacted than the head and middle canal reaches of the irrigation scheme. Generally, in the three canal reaches of the irrigation scheme the bulk density was in the recommended range which is 1 to 1.8 gm/cm^3.

The soil particle size distribution in percent for the three canal reaches (head, middle and tail) up to 120 cm depth were varied from 8 to 37%, 38 to 77 % and 8 to 31% for the sand, clay and silt soil fractions respectively. According to the USDA SCS Soil textural triangle (Appendix 2.2), the textural class for Golda irrigation scheme for all the selected canal reaches was found to be clay soil except at 0-30cm depth of middle canal reach was clay loam.

Table 4.3: Soil textural classes and bulk density

Canal reaches	Soil depth (cm)	Bulk density (gm/cm^3)	Particle size distribution(%)			Textural class
			Sand	Clay	Silt	
Head	0-30	1.01	32	52	16	Clay
	30-60	1.05	24	62	14	Clay
	60-90	1.17	20	72	8	Clay
	90-120	1.19	18	74	8	Clay
Average		1.11				
Middle	0-30	1.00	37	38	25	Clay loam
	30-60	1.10	27	54	19	Clay
	60-90	1.14	27	56	19	Clay
	90-120	1.24	23	60	17	Clay
Average		1.12				
Tail	0-30	1.04	16	53	31	Clay
	30-60	1.30	8	75	17	Clay
	60-90	1.31	16	67	17	Clay
	90-120	1.30	58	77	15	Clay
Average		1.25				

The soil pH, organic matter (OM), total nitrogen (N) and available phosphorus (P) in each canal reaches of the irrigation scheme were analyzed and the results were indicated in (Table 4.4). For the interpretation of the result, Frank (1990) soil analytical data results interpretation range was used. Average OM at head and middle reaches of the canal were 0.27 and 0.16 which were very low and at tail reach of the canal was 2.54 which was low in the range of (<2) and (2-5) respectively. There for, the fertility status of the area should be improved by adding crop residues and compost which can be increase the organic matter content of the soil.

Average soil pH were 5.5 to 5.6 for the three canal reaches of the irrigation scheme which was medium acid in the range of (5.3-6). Average N at head and middle canal reaches were 2 and 1.2 which were very high and at tail reach 0.12 which was medium in the range of (>0.3) and (0.125-0.225) respectively. Average available P at head and tail canal reaches were 3.45 and 3.15 which were very low and at middle 6.8 which was low in the range of (<5) and (5-8) respectively. This deficiency of P indicates that the area has a response for phosphorous fertilizer so that framers should be apply P fertilizer in the recommended rate.

Table 4.4: Soil pH, OM, total N and available P

Canal reaches	Soil depth (cm)	Soil Nutrient contents			
		pH	OM(%)	N(%)	P(ppm)
Head	0-30	5.80	0.50	2.94	3.68
	30-60	5.80	0.17	2.36	3.18
	60-90	5.50	0.24	1.79	3.06
	90-120	5.40	0.12	0.86	3.86
Average		5.60	0.27	2.00	3.45
Middle	0-30	5.70	0.22	2.38	8.18
	30-60	6.10	0.26	1.05	7.16
	60-90	5.60	0.05	0.52	6.42
	90-120	5.60	0.10	0.39	5.78
Average		5.50	0.16	1.20	6.80
Tail	0-30	5.60	4.65	0.23	3.22
	30-60	5.40	1.89	0.06	3.18
	60-90	5.30	1.89	0.09	3.11
	90-120	5.60	1.72	0.05	3.08
Average		5.50	2.54	0.12	3.15

4.2.1.2. Soil field capacity and permanent wilting point

The soil moisture at field capacity (FC), permanent wilting point (PWP) and total available water (TAW) with the interval of 30cm up to 120cm soil depth were analyzed and the results were indicated in (Table 4.5).The average calculated value of total available water of the irrigation scheme was 155.32mm/m within the acceptable range which was FAO (1998) recommended FC, PWP and TAM values for clay soil ranges from 320-400 mm/m, 200-240 mm/m and 120-200 mm/m respectively. This average value of TAW was used as input for determination of the crop water requirement in the CROPWAT 8.0 model.

Table 4.5: Soil FC, PWP and TAW

Canal reaches	Soil depth (cm)	FC (%)	PWP (%)	TAW (%)	TAW (mm)
Head	0-30	31.55	23.26	8.29	25.12
	30-60	29.00	21.41	7.59	23.91
	60-90	36.56	23.88	12.68	44.50
	90-120	38.3	27.21	11.09	39.60
Total					133.13
Middle	0-30	36.12	25.93	10.19	30.57
	30-60	35.52	26.12	9.40	28.26
	60-90	33.43	24.93	8.50	29.07
	90-120	36.44	27.80	8.64	32.14
Total					120.00
Tail	0-30	32.60	20.33	12.27	38.28
	30-60	36.00	24.41	11.59	45.20
	60-90	37.40	21.20	16.20	63.67
	90-120	41.43	25.21	16.22	65.70
Total					212.84
Average					155.32

Where: Average=(head total + middle total + tail total)/3

4.2.1.3. Soil infiltration rate

In the study area, the basic/constant infiltration rate was 0.72cm/hr which was attained after 150 minutes. Even though, the soil type of the study area was clay, the result was higher than the recommended value of FAO (2001), which is basic infiltration rate for clay soil is 0.1- 0.5cm/hr. The reason might be infiltration testing time, there was high temperature but this could not be the correct reason might be other factors. For the determination of crop water requirement using the CROPWAT 8.0 model, the maximum recommended value of the basic infiltration rate for clay soil, 0.5cm/hr was used.

4.2.2. Determination of reference evapotranspiration (ETo)

The variation of monthly mean value of reference evapotranspiration, effective rainfall and rain fall were indicated in (Figure 4.1). The ETo value from January to May and September to December was larger than the corresponding values effective rain fall but smaller values from June to August. The maximum and minimum ETo values were 4.66 and 2.67 mm/day in January and August respectively. The monthly ETo values for the study period from February to May 2019 were 5.03, 4.62, 5.43 and 4.0mm/day during February, March, April and May respectively. The monthly mean ETo value from January to December was 4.01 mm/day. But the monthly average ETo value for the study period was 4.77 mm/day. The yearly reference evapotranspiration of the study area was 1442.7mm, while the total ETo value for the study period was 572.4 mm.

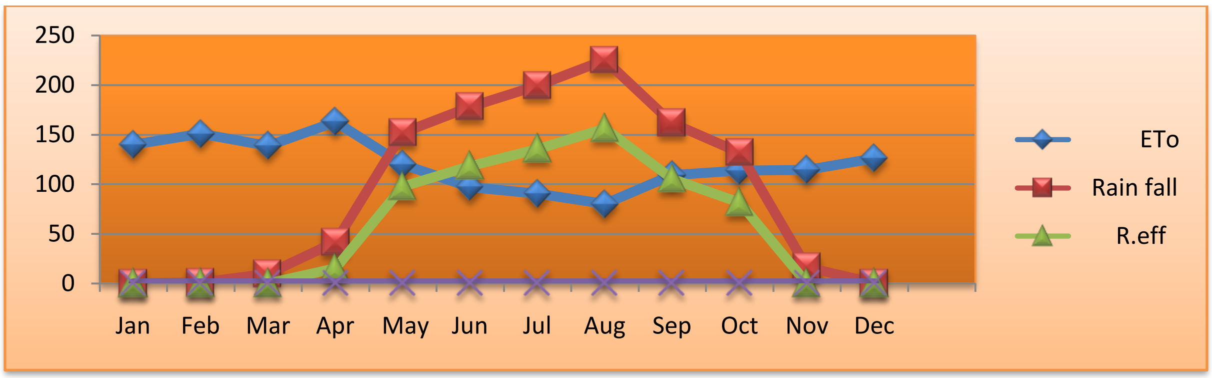

Figure 4.1: Mean monthly rain fall, effective rain fall and ETo values

4.2.3. Rainfall data analysis

Mean monthly rainfall profiles were generally uni-modal with peak in August as shown in (Figure 4.2). Rainfall is conditioned principally by migration of Inter-Tropical Convergence Zone which accounts for almost 100% of annual rainfall on average between March and November.

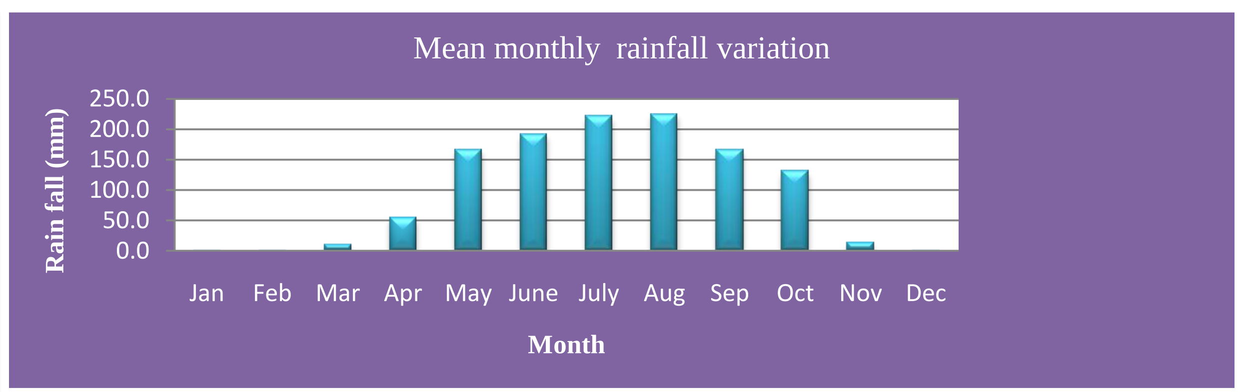

Figure 4.2: Mean monthly rain fall variations the irrigation scheme

4.2.4. Crop water and Irrigation water requirements

Crop water and irrigation water requirements were calculated using CROPWAT 8.0 model. The detailed crop water and irrigation water requirements of major irrigated crops in the irrigation scheme were indicated in (Appendix 1.3 to 1.7).The total seasonal crop water requirement maize, onion, tomato, potato and pepper were 536.4, 621.6, 535.1, 600.3 and 555mm respectively. The total seasonal net irrigation requirements were 444.2, 577, 507, 484 and 454mm for maize, onion, tomato, potato and pepper respectively.

The variation of seasonal crop water and irrigation water requirements for the irrigated crops in the study area were shown in (Figure 4.3).

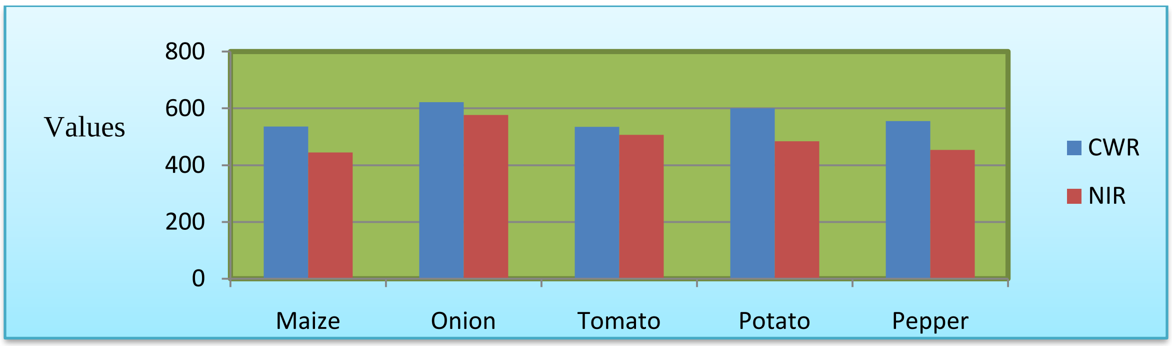

Figure 4.3: Variation of crop water and irrigation water requirement of the irrigation scheme

4.2.5. Irrigation scheduling

The farmers practiced and calculated irrigation intervals were vary in some crops as indicated in (Table 4.6). Farmers were applying the same irrigation interval in each growth stage of the irrigated crop but crops are required different amount of water at different irrigation interval within each growth stage. But crops require different irrigation interval in each growth stage because requirement of water is depends on growth stage and other factors. As a result of applied the same irrigation interval throughout the growth stage, irrigated crop production would have declined.

Table 4.6: Farmers practiced and calculated irrigation intervals in the irrigation scheme

S. No	Irrigated crops	Farmers practiced irrigation intervals(days)	Calculated irrigation intervals(days) at peak period
1	Maize	7	9
2	Onion	3-4	4
3	Tomato	3-4	4
4	Potato	3-4	5
5	Pepper	3-4	6

4.2.6. Irrigated crop of the scheme

The total area irrigated of the scheme was only 51 ha but the scheme was designed for the total irrigable command area of 62ha.This was indicated that about 18% of the designed irrigable area was out of production. The type of crops which were cultivated by the irrigation scheme users were shown in (Table 4.7). Maize was the most dominant irrigated crop in the irrigation scheme which accounts about 36.27% from the total area coverage. Secondly 21.10% from the total irrigated area was covered by onion and Chat was covered a smallest irrigated area which was 1.96%. A bout 62.733% of the total irrigated area was covered by horticultural crops which was good, because it is advisable to cultivate horticultural crops by irrigation to be effective in productivity.

Table 4.7: Irrigated crops and their area coverage in the irrigation scheme

S. No	Irrigated crops	Area coverage (ha)	Percentage from the total area (%)
1	Maize	18.50	36.27
2	Onion	10.75	21.10
3	Tomato	6.00	11.76
4	Potato	4.50	8.82
5	Pepper	3.50	6.86
6	Cabbage	2.50	4.90
7	Carrot	2.25	4.41
8	Banana	2.00	3.92
9	Chat	1.00	1.96
Total		51.00	100.00

4.2.7. Internal indicators

Even though, various authors have suggested many performance indicators, the types of indicators chosen depend on the purpose of performance assessment (Bos *et al*.,2005). In this study, on field water management was assessed in terms of application efficiency, storage efficiency and distribution uniformity.

4.2.7.1. Application efficiency

Irrigation management can improve efficiency by 5-20% by applying the right depth of water in the right place at the right time (Rose, 2006). The calculated application efficiencies of the three canal reaches were in the range of 50 – 53 %, which was indicated that the farmers were applying excess water to their fields (Table 4.8). This result was in line with Roger *et al.*(1997) was reported as, it is possible to have high application efficiency (50- 90%) can be used for general system type comparison and Lesley (2002) was reported as , it could be in the range of 50-80% . But the result was disagreed with FAO (1989) reported that the maximum attainable application efficiency ranges from 55%-70%.

Farmers were applying excess amount of water to their fields without considering the water requirement of the crop. From the result as we could see, the distance of the farm from water source never limit the irrigation users to apply excess amount of water.

Table 4. 8: Parameters and calculated application efficiencies

Canal reaches	Applied depth (mm)	Stored depth (mm)	Application efficiency (Ea)%
Head	146	77.38	53.00
Middle	133	68.10	51.20
Tail	128	64.90	50.70
Average application efficiency of the scheme			51.60

4.2.7.2. Storage efficiency

The adequacy of an irrigation event is expressed in terms of water requirement (storage efficiency). Storage efficiency has the advantage to know the applied irrigation water is satisfied the moisture deficit of the crop root zone . It is the most directly related to the crop yield since it will reflect the degree of soil moisture stress. Usually, under-irrigation in high probability rainfall areas is a good practice to conserve water but the degree of under-irrigation is a difficult question to answer at the farm level (Walker, 1989). The calculated value of storage efficiency at middle field was higher than head and tail fields as shown in (Table 4.9). The average storage efficiency of the scheme was 91.6% and nearly similar result was reported by Tedla (2007) at Bullinegero small scale irrigation scheme which was 92.8%. Depending on weather, type of soil and time span considered, storage efficiency might be as high as 90% (FAO,1992).

Table 4.9: Parameters and calculated storage efficiencies

Field	Stored water at root zone (mm)	Required water (mm)	Es (%)
Head	49.70	53.44	93
Middle	44.60	46.46	96
Tail	40.70	47.33	86
Average storage efficiency of the scheme			91.6

4.2.7.3. Water distribution uniformity

The distribution uniformity which describes how evenly irrigation is applied to the crop. There was high distribution uniformity at middle and tail field users than head irrigation fields which was 82% (Table 4.10).The average distribution uniformity was 80.76 % and Wakuma (2004) was reporting a similar result.

Table 4.10: Parameters and calculated water distribution uniformities

Field	Mean stored water (mm)	least quarter mean stored water (mm)	DU (%)
Head	50	40.14	80.28
Middle	44.7	36.66	82.00
Tail	40.7	33.38	82.00
Average distribution efficiency of the scheme			80.76

4.2.7.4. Deep percolation ratio

Since farmers were practicing closed end furrow, only deep percolation was considered. The magnitude of deep percolation loss varies with the type of crops grown. Crops with high application efficiencies had lowest DPR value and vice versa. The deep percolation ratio or high loss due to deep percolation was 44% which was obtained at middle field of the irrigation scheme as indicated in (Table 4.11) because of excess application of water before water depleted from the root zone. A higher deep percolation naturally results lower application efficiency. The average scheme loss due to deep percolation was 40% that means from the total depth of water applied, 40% water was lost.

Table 4.11: Parameters and calculated deep percolation ratio

Field	Ea(%)	RR(%)	DPR(%)
Head	60	0	40
Middle	56	0	44
Tail	64	0	36
Average efficiency of the scheme	60		40

4.2.7.5. Overall efficiency

The calculated overall efficiency of the irrigation scheme was 27.35% as indicated in (Table 4.12).This result was implied that the scheme was performed with low efficiency.

Table 4.12: Calculated over all efficiencies

Indicators	Efficiency of the scheme (%)
Conveyance efficiency	53.0
Application efficiency	51.6
Storage efficiency	91.6
Distribution efficiency	80.76
Deep Percolation ratio	40.0
Overall efficiency of the scheme	27.35

4.2.8. External indicators

4.2.8.1. Agricultural output indicators

Under this land and water productivity indicators were analyzed. The output per cropped area shows the response of each cropped area on generating gross return within the available water; the capacity of land productivity. While the output per unit water consumed describes the outcome gained through using a meter cube of applied water; the capacity of water productivity.

Estimation of total output production: A total output production value was calculated from one production season (2018/2019) because lack of other year production data and farmers were producing once in the irrigation scheme.

Table 4.13: Irrigated crop type, parameters and output production values

Irrigated Crops	Area (ha) (a)	Yield (Ql/ha) (b)	Total yield(Ql) (c)=(a)*(b)	Price (birr/Ql) (d)	Production (birr) (e)=(c)*(d)	Production (US$) (f)=(e)/(28.9785birr)
Maize	18.5	30	555	700	388,500	13,406.44
Onion	10.75	80	860	1,000	860,000	29,677.07
Tomato	6.00	80	480	1,000	480,000	16,563.97
Potato	4.50	90	405	1,000	405,000	13,975.83
Pepper	3.50	8	28	4,000	112,000	3,864.92
Cabbage	2.50	85	212.5	2,600	552,500	19,065.79
Carrot	2.25	83	186.7	54,000	747,000	25,777.64
Banana	2.00	105	210	1,000	420,000	14,493.45
Chat	1.00	60	60	40,000	2,400,000	82,819.74
Total	51	621	2997.25	56,300	6,365,000	219,644.80

Ql: quintal & 1Ql=100kg
1 US$ = 28.9786 Ethiopian Birr rate, July, 2019

A. Land productivity indicators

Land productivity was evaluated using the two indicators which were output per unit irrigated area and output per command area.

I. Output per unit irrigated area (OPUIA)

According to the analysis of the result the output per unit irrigated area was 4,306.76US$/ha as indicated in (Table 4.14).This finding shows that the scheme has better value than Haluk small scale irrigation scheme found in Adami Tulu Jido Kombolcha Woreda, Central rift valley of Ethiopia, the output per irrigated area was 2,852.77US$/ha as reported by Shiberu *et al*.(2019). Also nearly similar result was reported by Tesfaye (2018) at Wosha irrigation scheme which was 4,214.97US$/. The similar result also was reported by Degirmenci *et al*. (2003) who found the output per irrigated area was varied between 308 and 5771 US$/ha for twelve irrigation schemes found in the Southeastern Anatolia Project.

II. Output per unit command area (OPUCA)

It is an indication of whether all the command areas generating returns or not. The output per unit command area of the irrigation scheme was 3,542.66US$/ha as indicated in (Table 4.14). This result was nearly similar with Wondatir (2016) report, the output per unit command area of

Jari small scale irrigation scheme was 3,464US$/ha. The result was higher than results obtain in Turkey (hayrabolu irrigation scheme) and in Ethiopia (Dodicha small scale irrigation scheme) values of 709 US$/ha and 1,278.59US$/ha reported by Sener *et al*.(2007) and Shiberu *et al*.(2019) respectively. However the calculated value was smaller than values of 4,746US$/ha and 8,704US$/ha at Selamko and Shina-Hamusit small scale irrigation schemes respectively (Shenkut,2015).

B. Water productivity indicators

I. Output per unit irrigation delivered (OPUID)

This indicator shows the revenue from agricultural output for each cubic meter of irrigation water supplied. It is a useful external indicator because it addresses output per drop of water irrigation actually delivered to the user. The output per irrigation delivered was calculated and the result was 1.42 as indicated in (Table 4.14).

II. Output per unit water consumed (OPUWC)

The output per unit water consumed is used to describe the return on water actually consumed by the crop. This indicator gives due attention to the water consumed by the scheme and tell us how water is efficiently utilized by the scheme from economic point of view. The values for this indicator was found to be 0.69US$/$m^3$ as indicated in (Table 4.14) and it was in the range of 0.03-0.91US$/$m^3$ (Molden *et al*.,1998).This result shows that the water use efficiency is lower than Selamko irrigation scheme which was 1.15US$/$m^3$ as Shenkut (2015) reported.

Table 4.14: Parameters and calculated land and water productivity indicators

Parameters	Values
Irrigated cropped area (ha)	51
Command cropped area (ha)	62
Irrigation water supplied(m^3)	4,403,051
Water consumed ET(m^3)	317,054.5
Production (US$)	219,644.80
OPUIA (US$/ha)	4,306.76
OPUCA (US$/ha)	3,542.66
OPUID (US$/$m^3$)	1.42
OPUWC (US$/$m^3$)	0.69

4.2.8.2. Physical indicators

The irrigation scheme of irrigable area, initial irrigated area and currently irrigated areas were 62ha, 51ha & 51ha respectively. Irrigation ratio and sustainability of irrigated area were calculated using equation 3.40 & 3.41 respectively.

A. Irrigation ratio

The irrigation ratio of the scheme was 0.82 which means 82% of the command area was currently under irrigation and about 18% of the command area was not under irrigation during the study period as indicated in (Figure 4.4).The current finding in line with a similar result was reported by Dejen *et al*.(2012) at Wedecha sub system of Gohaworki irrigation scheme. The irrigation ratio of the scheme was better than Dodicha small scale irrigation scheme as reported by Shiberu *et al*.(2019) which was 0.59.

B. Sustainability of irrigated area

Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated area and would imply more sustainable irrigation (Bos *et al*., 2005). Sustainability of irrigated area was 1.0 as shown below in (Figure 4.4). As the result indicates there was no contraction and expanding of initial irrigated area. In principle, neither extension nor shrinkage is desired (Dejen *et al*.,2016). Nearly similar result was reported by Kassa and Ayana (2016), at Tigray, Ethiopia (Tahtay Tsalit small scale irrigation scheme) was 1.08.

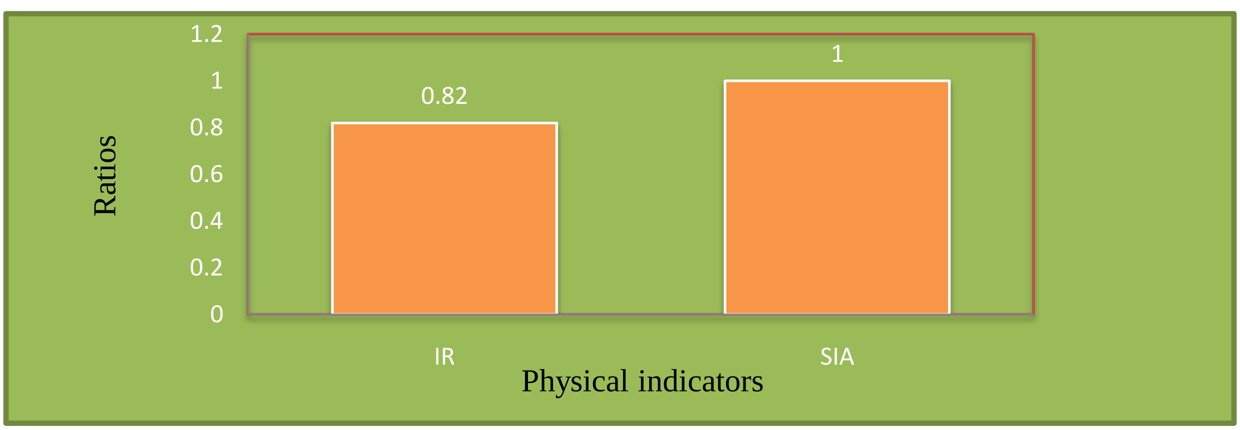

Figure 4.4: Calculated value of irrigation ratio & sustainability of irrigated area

4.2.8.3. Financial indicator

A. Gross return on investment

For the determination of gross return on investment, 2018/2019 production values was used due to lack of long term production value data. As a result the cost of irrigation infrastructures were done in cost in present net worth and this cost was only considers on irrigable area rather than command area. The calculated gross return on investment was 54% as indicated in (Table 4.15). Nearly similar results were reported by Wondatir (2016) and Molden *et al*.(1998), 55% in Jari and 52% in India respectively. Even though the GRI was good, irrigation beneficiaries should be expected to increase their production by produce more than once per year in the irrigation scheme.

Table 4.15: Investment cost of the irrigation system

Irrigable area (ha)	N	Cost (birr)	Cost (birr/ha)	Cost in PNW (birr/ha)	Production cost (birr/ha)	GRI (%)
51	6	6,669,861.7	130,781.6	231,687.6	124,803.9	54

N- Number of service years

4.3. Organizational Setups and Performance for Irrigation Water Management and Scheme Maintenance

The organizational setup of Water Users Association with collective participation of individual user's in irrigation activities has positive impact on sustainable management (Sharma *et al.*,2016).

4.3.1. Demographic characteristics of the irrigation scheme beneficiaries

For the assessment of house hold characteristics of the irrigation scheme household survey was conducted. According to the survey result of the beneficiaries, most of the irrigation scheme users was male headed household which accounts about 79.4% as indicated in (Table 4.16). Regarding to age, about 89.7% of beneficiary house hold heads were in the range of 20-60 years. Illiterate house hold heads were the dominant beneficiaries of the irrigation scheme that accounts about 72.1%. About 91.2% of the irrigation scheme beneficiary house hold head was married.

Table 4.16: Demographic characteristics of the beneficiary house hold heads

Characteristics		(N=68)	
		Frequency	Percent
Sex	Male	54	79.4
	Female	14	20.6
Age of house hold head	20-60 years	61	89.7
	>60 years	7	10.3
Educational level			
Illiterate		49	72.1
Read & Wright only		12	17.6
Elementary		6	8.8
High school		1	1.5
Marital status			
Married		62	91.2
Widowed		2	2.9
Divorced		4	5.9

Where: N: Number of respondents

4.3.2. Organizational structure of WUAs

In Golda irrigation scheme there were five Gotes[4] and three ketenas[5] which were organized for management purpose. There was no clear organizational structure of water users association rather they were organized as water users committee which has been eleven members; nine were males and two of them were females. The WUA committees are male dominated and the views of women are hardly represented in the decision making. The structure was as Chair man, Vice-chair man and Secretary. When I was discussing with Woreda experts, they were organized for the purpose of only water allocation or arranging water distribution period and conflict management. The water committees were not work their tasks accordingly because they were need incentives.

[4] A small parts of kebele
[5] Local water management organization levels

4.3.3. Bylaws and fee collection

In Golda small scale irrigation scheme there was no clear written rules and regulations related to water allocation and distribution. As the Woreda irrigation expert told to me, the new proclamation was reaches to Woreda but not applicable, they were in the process of training to implement the proclamation of water users association. The absence of bylaws increase illegal water users and thefts who were taking the gate.

Fee collection was not applicable in the irrigation scheme due to this beneficiaries were not care about the scheme and they were irrigated crops once per year, during rainy season the area was not covered by crops which was covered with weeds. So that, fee collection should be applicable that helps for maintenance purpose.

4.3.4. Participations of users in operation and maintenance

The irrigation users participation at the time of planning and construction period had a positive impact to create sense of ownership and sustainability of the irrigation scheme. According to house hold field survey users were never participate during planning as well as construction of the diversion wire. The regional government was taken the responsibility, but they were interesting on the diversion site. Beneficiaries did not participate in the maintenance of the irrigation scheme, but as Limperier *et al*.(2004) states that, this task was the mandate of WUAs. Irrigation users were participated in cleaning of canals before starting irrigation practice. As 67.6% of irrigation users respond that the maintenance condition of the irrigation scheme was bad as indicated in (Table 4.17).

Table 4.17: Perceptions of respondents on the maintenance condition of irrigation

Maintenance conditions	Frequency	Percent
Good	5	7.4
Medium	11	16.2
Bad	46	67.6
Very bad	6	8.8
Total	68	100

According to 32.2% of beneficiaries respond, the location of structural failure was around head work. Since the irrigation canal is earthen erosion problems was happened and division boxes were not functioned properly as 57.4% of beneficiaries respond (Table 4.18). Gates were lost due to thefts, who were from irrigation users. Therefore, irrigation users were facing to control the flow of water to their field, as a result they were forced to use local water control mechanisms which aggravates high loss of water.

Table 4.18: Respondent's observation on location of structural failure

Location	Frequency	Percent
Head work	22	32.3
Canal	39	57.4
Other structures	7	10.3
Total	68	100

4.3.5. Water allocation and distributions

The water allocation and distribution was implemented by water users committee. The allocation of water was rigid rotational which was fixed time and it was not consider the area size of irrigation beneficiaries. Whatever they have, for all the same amount of water was distributed. The distribution was also never consider the type of crop and their growth stage, for different irrigated crops the same distribution was applied; this leads to low production and productivity. As 75% of beneficiaries respond, there was fair distribution of water but some beneficiaries respond that due to head users and illegal water users unfair distribution was happened (Table 4.20). Head and Illegal water users were above the control of water users committee so that they did not respect their time of rotation. As a result, tail users were faced water scarcity and irrigated crops were wilted. There for, water users committee should be strengthen to keep their performance.

Table 4.19: Main criteria used to scheduling irrigation

Scheduling criteria	Frequency	Percent
Condition of the plant	3	4.4
Fixed time interval	59	86.8
Water supply availability	6	8.8
Total	68	100

Table 4.20: Levels of water distribution

Levels	Frequency	Percent
Very fair	3	4.4
Fair	51	75
Un fair	14	20.6
Total	68	100

Table 4.21: Reasons for unfair distribution of water

Reason	Frequency	Percent
Head users	6	42.8
Corrupted official/WUG	2	14.3
Illegal water users	4	28.6
Non-reliability of water sources	2	14.3
Total	14	100

4.3.6. Conflicts and conflict managements

Most conflicts were happened among irrigation beneficiaries especially between head and tail users. The capacity of the scheme was decrease time to time so that water scarcity was happened and there was a computation with in irrigation water users, this leads to conflict. Water thefts who were not follow their irrigation turns was challenging water user committees due to absence of bylaws in the irrigation scheme. The water user committees were tried to solve the conflict by local negotiation. There for, the kebele administer staffs should be support the water user committees in conflict resolution.

Table 4.22 : Beneficiaries response on conflict over irrigation water

Response	Frequency	Percent
Yes	43	63.2
No	25	36.8
Total	68	100

Table 3.23: Causes of conflicts over irrigation water

Cause of conflict	Frequency	Percent
Water scarcity	19	44.2
Computation due to increasing number of water users	7	16.3
Water theft	17	39.5
Total	43	100

5. SUMMARY AND CONCLUSTIONS

5.1. Summary

The study was conducted to evaluate the performance of Golda small scale irrigation scheme located in Assosa Woreda, Benishangul Gumuz regional state of Ethiopia. Water delivery performance, on field water management performance and organizational setup and performances for irrigation water management of the scheme was evaluated. Water delivery performance was evaluated using conveyance efficiency, relative water supply and relative irrigation supply. On field water management performance of the scheme was evaluated using both internal and standardized external indicators established by IWMI. From internal indicators water application efficiency, water storage efficiency, distribution uniformity, deep percolation ratio and overall efficiency and external indicators include agricultural output, physical and financial indicators were used. The organizational setup and performance for irrigation water management and scheme maintenance was evaluated by preparing sample questionnaires for house hold survey.

The textural class of the soil was clay and the bulk density was ranged from 1.11gm/cm^3 to 1.25gm/cm^3.The soil was medium acid and had very low to low organic matter content, available phosphorus and medium to high total nitrogen. Thus, the soil had high response to phosphorus fertilizer that could be increase the production of the scheme. The total water holding capacity of the soil was ranged from 133.13mm to 155.32mm.

The main and tertiary canals efficiencies were low due to unlined throughout their lengths so that increase seepage loss, sedimentation, eroded the side of canals. Lack of frequent canal cleaning and maintenance also the cause of low efficiencies of canals. There were sufficient relative irrigation supply and high relative water supply which was beyond the crop demand. The application efficiency was relatively low due to irrigation users were applied excess amount of water without considering water requirement of the crop. Storage efficiency was high which indicates there was adequacy of irrigation or the applied depth of water could be satisfied the water requirement of crops. The distribution uniformity was about 80.76% which means that the applied irrigation depth was evenly distributed to the irrigated crops. From the applied depth of water, about 40% was lost due to deep percolation. The overall efficiency was 27.35% which was poor.

The agricultural outputs which were output per unit command area, output per unit irrigated area, output per water diverted and output per unit water consumed values 3542.66US$, 4306.76US$, 1.42US$ and 0.69US$ respectively. About 82% of the irrigable area of the scheme was under irrigation that means 18% was out of production. The sustainability of irrigated area was one which means neither expand nor contract. From the irrigation scheme, 54% of gross return on investment was obtained.

In the irrigation scheme, there was no clear organizational structure, bylaws and fee collection. Strong water users association have a great contribution on the performance of the irrigation scheme but in Golda irrigation scheme there was no strong water users association. Unfair distribution of water was happened because head users did not keep their rotational turns. Absence of bylaws increase illegal water users and this leads to scarcity of water at tail reach of canal users. Due to absence of fee collection beneficiaries were produce in the irrigation scheme once per year. The participation of irrigation users on operation and maintenance was bad. Beneficiaries did not have sense of ownership on irrigation scheme because they were taking metal sheet gates. The allocation of water was rigid rotational which was fixed time and it was not consider the area size of irrigation beneficiaries. Even though conflicts were happened, the solving mechanisms were poor.

Generally, based on evaluation findings using the minimum indicators the scheme requires improvement to achieve construction goals and its performance. Finally, the result of this study will have an input to take improvement measures for the sustainability the irrigation scheme.

5.2. Conclusions

From the results obtained, the following conclusions are forwarded.

- ✓ The conveyance efficiency of the system was found to be poor. Thus, to increase the efficiency, the canals should be cleaned and soil and water conservation structures should be constructed to protect canal banks from erosion.
- ✓ Supporting by irrigation experts; the scheme requires proper irrigation water management like irrigation scheduling: applying the required amount of water at the right time that could increase application efficiency.
- ✓ The organic matter content and available phosphorous deficiency should be improved by mulching with crop residues, using compost and applying the recommended phosphorous fertilizer that could increase on field water management performance of the scheme.
- ✓ The Irrigation scheme users should produce more than once per year to get high production that could increase gross return of the investment.
- ✓ Clear organizational structure would be required for making the irrigation users responsible which helps the sustainability of the irrigation scheme.
- ✓ Fee collection should be applied that could increase the irrigation users sense of ownership and also brings economic value.
- ✓ The proclamation regarding to water users association should be implemented.
- ✓ The water users committee should be strengthened by training and there should be monitoring and evaluation by respected bodies to increase their performance .

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APPENDICES

Appendix 1: Tables

Appendix 1.1: Average monthly profile of climatic variables at the irrigation scheme

Month	Max Temp	Mini Temp	Humidity	Wind Sp.	Sunshine	Solar Rad.	ETo
	(^{0}C)	(^{0}C)	(%)	(Km/d)	(Hours)	(MJ/m2/d)	(mm/d)
January	29.9	14.5	54	147	9.3	20.9	4.66
February	31.5	15.7	53	147	8.5	21.1	5.03
March	31.8	17	54	121	6	18.5	4.62
April	31.5	17.2	56	147	8.7	23	5.43
May	28	16.7	79	147	6	18.4	4
June	25.2	15.5	86	121	4.7	16.1	3.23
July	23.9	15.1	87	121	4.1	15.3	3.01
August	23.9	14.9	88	121	2.3	12.9	2.67
September	25.6	14.8	83	121	6	18.5	3.64
October	25.8	14.9	78	121	7.2	19.5	3.79
November	27.4	14.4	72	121	7.7	18.9	3.81
December	29.3	14.6	63	147	8.3	19	4.2

Appendix 1.2: Average monthly rain fall and effective rain fall at the irrigation scheme

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RainF.	0	0	31	32	118	189	287	208	207	103	21	0
Reff	0	0	29.5	30.4	95.7	131.8	153.7	138.8	138.4	86	20.3	0

Appendix 1.3: Maize growth stage, effective rainfall, crop water and irrigation water requirement during growing period

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.3	1.4	1.4	0	1.4
Jan	2	Init	0.3	1.43	14.3	0	14.3
Jan	3	Deve	0.31	1.53	16.8	0	16.8
Feb	1	Deve	0.49	2.54	25.4	0	25.4
Feb	2	Deve	0.75	4.02	40.2	0	40.2
Feb	3	Deve	0.98	5.2	41.6	0.1	41.5
Mar	1	Mid	1.18	6.16	61.6	7.4	54.1
Mar	2	Mid	1.2	6.22	62.2	11.1	51.1
Mar	3	Mid	1.2	6.27	69	10.8	58.2
Apr	1	Mid	1.2	6.4	64	8	56
Apr	2	Late	1.14	6.17	61.7	7.1	54.6
Apr	3	Late	0.88	4.4	44	15.3	28.7
May	1	Late	0.59	2.74	27.4	25.5	1.8
May	2	Late	0.39	1.68	6.7	13.3	0
					536.4	98.7	444.2

Appendix 1.4: Onion growth stage, effective rainfall, crop water and irrigation water requirement during growing period

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.4	1.45	14.5	12.7	1.8
Nov	2	Init	0.4	1.55	15.5	4.7	10.8
Nov	3	Deve	0.43	1.74	17.4	3.1	14.3
Dec	1	Deve	0.6	2.57	25.7	0.1	25.6
Dec	2	Deve	0.79	3.55	35.5	0	35.5
Dec	3	Deve	0.99	4.55	50	0	50
Jan	1	Mid	1.15	5.4	54	0	54
Jan	2	Mid	1.17	5.57	55.7	0	55.7
Jan	3	Mid	1.17	5.79	63.7	0	63.7
Feb	1	Mid	1.17	6.01	60.1	0	60.1
Feb	2	Late	1.16	6.22	62.2	0	62.2
Feb	3	Late	1.1	5.81	46.5	0.1	46.4
Mar	1	Late	1.01	5.26	52.6	7.4	45.2
Mar	2	Late	0.9	4.67	46.7	11.1	35.6
Mar	3	Late	0.83	4.31	21.5	4.9	16.1
					621.6	44.1	577

Appendix 1.5: Tomato growth stage, effective rainfall, crop water and irrigation water requirement during growing period

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.45	1.63	16.3	12.7	3.7
Nov	2	Init	0.45	1.74	17.4	4.7	12.7
Nov	3	Deve	0.48	1.95	19.5	3.1	16.4
Dec	1	Deve	0.65	2.77	27.7	0.1	27.6
Dec	2	Deve	0.84	3.76	37.6	0	37.6
Dec	3	Mid	1.04	4.75	52.2	0	52.2
Jan	1	Mid	1.12	5.22	52.2	0	52.2
Jan	2	Mid	1.12	5.33	53.3	0	53.3
Jan	3	Mid	1.12	5.54	61	0	61
Feb	1	Late	1.11	5.74	57.4	0	57.4
Feb	2	Late	1.04	5.56	55.6	0	55.6
Feb	3	Late	0.95	5.01	40.1	0.1	40
Mar	1	Late	0.86	4.48	44.8	7.4	37.4
					535.1	28.1	507

Appendix 1.6: Potato growth stage, effective rainfall, crop water and irrigation water requirement during growing period

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.5	2.34	2.3	0	2.3
Jan	2	Init	0.5	2.39	23.9	0	23.9
Jan	3	Init	0.5	2.48	27.3	0	27.3
Feb	1	Deve	0.56	2.89	28.9	0	28.9
Feb	2	Deve	0.77	4.12	41.2	0	41.2
Feb	3	Deve	0.97	5.12	40.9	0.1	40.8
Mar	1	Mid	1.13	5.91	59.1	7.4	51.7
Mar	2	Mid	1.15	5.96	59.6	11.1	48.5
Mar	3	Mid	1.15	6.01	66.1	10.8	55.3
Apr	1	Mid	1.15	6.13	61.3	8	53.4
Apr	2	Late	1.15	6.21	62.1	7.1	55.1
Apr	3	Late	1.06	5.35	53.5	15.3	38.2
May	1	Late	0.93	4.29	42.9	25.5	17.4
May	2	Late	0.8	3.43	30.9	29.9	0
					600.3	115.3	484

Appendix 1.7: Pepper growth stage, effective rainfall, crop water and irrigation water requirement during growing period

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.6	2.81	2.8	0	2.8
Jan	2	Init	0.6	2.87	28.7	0	28.7
Jan	3	Init	0.6	2.98	32.8	0	32.8
Feb	1	Deve	0.6	3.11	31.1	0	31.1
Feb	2	Deve	0.7	3.73	37.3	0	37.3
Feb	3	Deve	0.81	4.3	34.4	0.1	34.3
Mar	1	Deve	0.93	4.87	48.7	7.4	41.2
Mar	2	Mid	1.04	5.38	53.8	11.1	42.7
Mar	3	Mid	1.05	5.49	60.4	10.8	49.6
Apr	1	Mid	1.05	5.61	56.1	8	48.1
Apr	2	Mid	1.05	5.69	56.9	7.1	49.8
Apr	3	Late	1.04	5.21	52.1	15.3	36.8
May	1	Late	0.96	4.45	44.5	25.5	18.9
May	2	Late	0.91	3.88	15.5	13.3	0
					555	98.7	454.1

Appendix 1.8: Soil infiltration rate of the scheme

Cumul.	Elapsed	Reading	Reading	Incremen	Infiltrat.	Inifiltrat.	Cumul.	Cumulativ	Elapsed
Time (min)	time	before	after	tal infi.	rate	rate	infiltrat.	infiltrat.	time
	min	Filling (cm)	Filling (cm)	cm	cm/min	cm/hr	cm	Rate (mm/day)	hr
0	0	0	11	0			0	0	0
0.5	0.5	8	8	3	6	360	3	86400	0.00833
1	0.5	5.5	5.5	2.5	5	300	5.5	72000	0.00833
2	1	3.5	11	2	2	120	7.5	28800	0.01667
5	3	9.5	9.5	1.5	0.5	30	9	7200	0.05
10	5	8.4	8.4	1.1	0.22	13.2	10.1	3168	0.08333
20	10	7.6	7.6	0.8	0.08	4.8	10.9	1152	0.16667
40	20	7	7	0.6	0.03	1.8	11.5	432	0.33333
60	20	6.5	6.5	0.5	0.03	1.8	12	432	0.33333
90	30	6.1	11	0.4	0.013	0.78	12.4	187.2	0.5
120	30	10.62	10.62	0.38	0.013	0.78	12.78	187.2	0.5
150	30	10.26	10.26	0.36	0.012	0.72	13.14	172.8	0.5
180	30	9.91	9.91	0.35	0.012	0.72	13.49	172.8	0.5
210	30	9.56		0.35	0.012	0.72	13.84	172.8	0.5

Appendix 1.9: Main canal efficiency and losses

observation	Qin	Qout	Ec	losses
points(m)	l/se	l/s		(ls/100m)
100	102.4	90.2	0.88086	12.2
200	98.3	80.7	0.82096	17.6
300	93.7	74	0.78975	19.7
400	88.6	72	0.81264	16.6
500	82.7	70.3	0.85006	12.4
600	74.8	58	0.7754	16.8
700	70.1	56	0.79886	14.1
800	66.2	50.7	0.76586	15.5
900	58.7	42.8	0.72913	15.9
1000	54.5	34.6	0.63486	19.9
average			0.78584	16.07

Appendix 1.10: Tertiary canals conveyance efficiency and losses

Canals	Observation	Qin	Qout	Ec	losses
	points(m)	l/se	l/s		(ls/100m)
TC-1	1	23.5	18	0.76596	5.5
	2	15.2	9	0.59211	6.2
	3	9.1	6.2	0.68132	2.9
average				0.67979	4.86667
TC-2	1	26	17.7	0.68077	8.3
	2	20.8	16.8	0.80769	4
	3	12.1	7	0.57851	5.1
average				0.68899	5.8
TC-3	1	28.3	18.9	0.66784	9.4
	2	22.4	17.6	0.78571	4.8
	3	10.8	6.1	0.56481	4.7
average				0.67279	6.3

Appendix1.11:Ea

Canal reach	Irrigation	Time(sec)	Head(cm)	q(l/s)	Applied depth	Stored depth	Ea
Head	events				(mm)	(mm)	%
	1	21345	6	2.3	132.54	68.43	51.63
	2	23568	7	2.9	164.75	95.24	54.2
	3	26524	8	3.5	153.18	90.74	53.8
					146	77.38	53
Middle	1	27345	6	2.3	132.54	68.43	51.63
	2	24632	7	2.9	164.75	95.24	54.2
	3	34641	8	3.5	153.18	90.74	53.8
					133	68.1	51.2
Tail	1	22857	6	2.3	132.54	68.43	51.63
	2	25416	7	2.9	164.75	95.24	54.2
	3	31270	8	3.5	153.18	90.74	53.8
					128	64.9	50.7
Average application efficiency							51.6

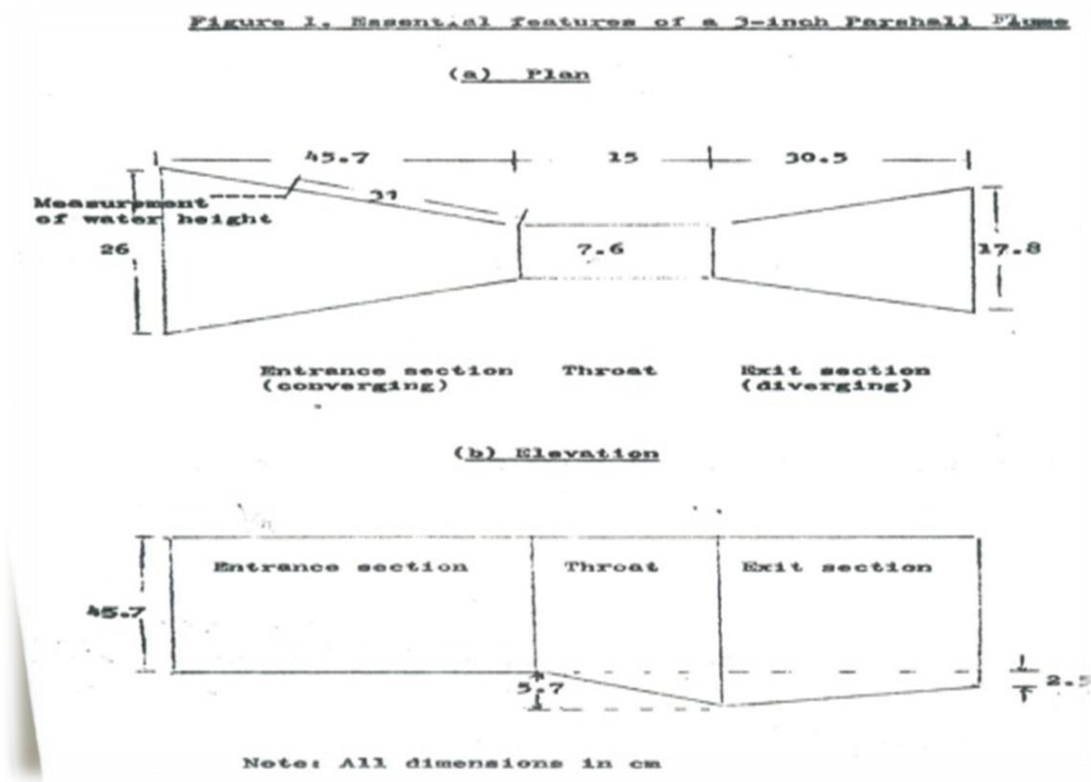
Appendix 1.12: Determination of storage efficiency

Canal reaches	Irrigation event	Stored water at root	Requirement water	Es
		zone (mm)	(mm)	(%)
Head	1	53.59	58.35	
	2	67.37	72.97	92
	3	58.63	62.91	94
		49.7	53.44	95
				93
Middle	1	39.66	42.45	
	2	54.81	59.71	96.6
	3	41.06	43.22	95.3
	average	44.6	46.46	96
				96
Tail	1	28.28	32.02	
	2	23.36	29.4	88
	3	18.58	22.33	83
		40.7	47.33	87
				86
Average storage efficiency				91.6

Appendix 1.13: Distribution uniformity of the irrigation scheme

Canal	Irr.	Total stored water at the depth of 120cm in the root zone											
		Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	average	Zlqm	Ed(%)
Head	1	50.5	52.7	54	36.4	45.8	41.2	50.3	48.1	50.7	47.7444		
	2	55.6	53	58	38.2	50.3	53.7	51.8	58.9	53.4	52.5444		
	3	52.7	55	51.1	37.6	47.4	47.9	51	50.7	51.3	49.4111		
												40.1	80.28
Middle	1	40.5	46.2	48.1	46.4	45.7	39.4	43.1	38.7	55.6	44.8556		
	2	51.3	59.4	56.7	48.2	47.3	41.5	58.8	42.1	58.4	51.5222		
	3	32.3	35.6	40.8	41.4	35.7	31.5	37	33	54.3	37.9556		
												36.7	82
Tail	1	26.3	30.5	19.7	23.1	18.9	34	25.8	22.6	24.5	25.0444		
	2	31	35.7	28.2	25	21.7	38.6	27.4	26.1	25.8	28.8333		
	3	54.7	58	64.1	47.6	58.4	52.9	51	60.7	54.3	55.7444		
												33.4	82
Average distribution efficiency													80.76

Appendix 2: Figures



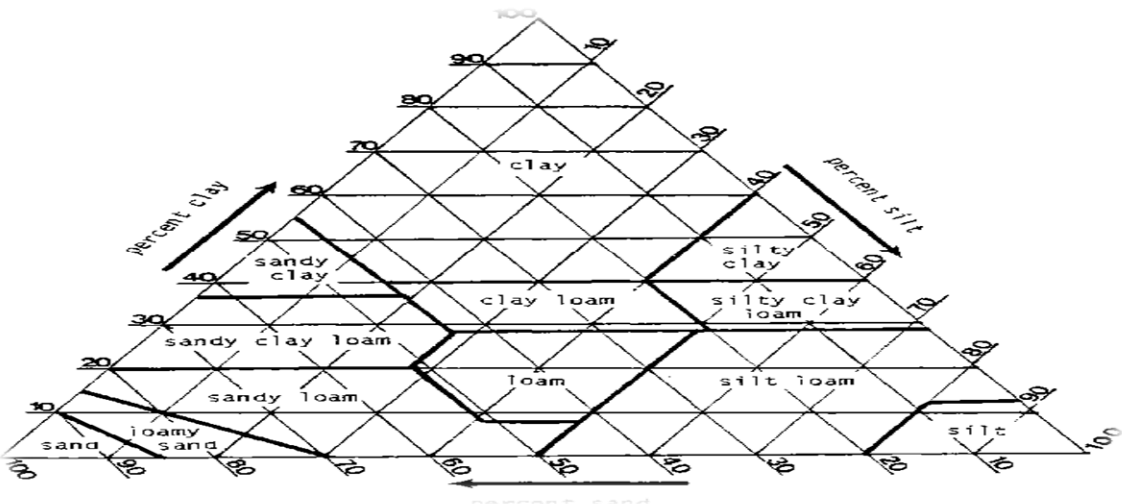
Appendix 2.1: Essential features of 3 inch partial flume

Parshall flume is made up of three sections: a converging section with a level floor, a throat section with a sliding sloping floor and a diverging section with an upward sloping floor.

Dimension (mm).

D	A	H	W	C	B	F	G	E	N	K
259	311	467	76.2	178	457	152	305	457	57	25

Where: W: throat width, H: length of side wall of converging section, A: distance back from end of crest to gage point, B: axial length of converging section, D: width of upstream end of flume, C: width of downstream end of flume, F: length of throat and E: gage height (Skogerboe *et al*., 1966).



Appendix 2.2: Soil textural class triangle(from Handbook No. 436 U.S. Department of Agriculture, Washington, D.C., 1975)

Appendix 2.3: Installation of double ring inifiltrometer at field of the irrigation scheme

Appendix 2.4 : Low water level in the main canal due to sedimentation, un-clean grass, seepage and erosion

Appendix 2.5: Water stressed and poor field management onion filed at irrigation scheme

Appendix 2.6: Farmers local water control/gate and division box in the main canal of irrigation scheme

Appendix 2.7: Team of interviewers and house hold field survey

Appendix 3: questionnaires

Appendix 3.1:Sample Questionnaires for evaluation of organizational setups and performance for irrigation water management and scheme maintenance of Golda small scale irrigation scheme

Enumerator Name.____
Farmer Name ____
Location : Head Middle Tail

A. Household characteristics and HH Resources

1. Household head Male ______________ Female _________ Age ___________Educational Level_________
2. Family size F______ M_______
2.1.<20yrs 2.2.20-60yrs 2.3.>60yrs
3. Marital status of the respondent:
3.1.Married 3.2.Widowed 3.3. Divorced 3.4. Unmarried
4. Literacy level of the household:
4.1.illiterate 4.2.Elementary 4.3.Read and write only 4.4. High school

B. Project Evaluation

I. Planning

1. Who initiate the idea of constructing the diversion wire?
1.1. Local people
1.2. DA
1.3. Project staff
1.4. Others...............
2. If it is not the local people, have you agreed about the construction of the structures?
Yes No
If no
Why? ____
3. Have you been consulted for the construction?
Yes No
4. How was the planning process?
4.1. Group discussion
4.2. Simple information by DAs
4.3. Simple information by PA leader
4.4. Simple information by project personnel
4.5. Have you participate in planning of any project?
Yes No

II. Design/ layout

1. Where you agreed on the project/dam site?
2. What is your opinion about the site of the diversion? ________________________________
3. Did you face any problem because of the site selection?
Yes No
If yes, what was the problem? ____

III. Implementation

1. Do you participate in the construction of the diversion structure and irrigation canals?
Yes No
1.1. If yes, in what way you participate?
1.1.1. Voluntarily without payment
1.1.2. By rule without payment (mass mobilization)
1.1.3. Through payment in the form of money
1.1.4. Through payment in the form of food aid (EGS)
1.4.5. Through payment in the form of FFW
1.1.6. Both with and without payment
2. Do you use the irrigation project by now?
Yes No

If No, why?____
3. Do you know the cause of failure?
Yes No
If yes, what are they?____
3.1. Seepage from the head work and/or the canals and its structure
3.2. Structural failure
3.3. Design problem
4. Do you see any structural failure?
Yes No
If yes, which structures?
4.1. The head work
4.2. The canals
4.3. The canal structures
4.4. All
4.5. Other structures (indicate)____
5. Do you see any seepage on the headwork, canals and canal structures?
Yes No

C. Water management

1. What criteria should you used to decide when to irrigated crops?
1.1 .Wait until see signs of wilting on the leaves
1.2. check the soil near the roots
1.3. When it is dry, I irrigate
1.4. irrigate every day
2. Do you think your yield is reduced because you cannot apply enough water to your crop?
Yes No
3. Who makes decisions on the sequence of using irrigation water? ______________________
4. What is the system of water allocation?
4.1. Proportional to the amount of land you have under irrigation.
4.2. Equal division among members of the association
4.3. Specify if any other system____
5. Does the community have a system of rule for controlling water distribution default?
Yes No
6. Are there special considerations for crop-type and stage of growth during water allocation?
Yes No
7.Are there any problems during the application of irrigation water? yes / no
7.1. If yes, what are they? (rank them)
7.1.1.Downstream conflict 7.1.2. Shorter time allowed for irrigation water flow
7.1.3.Water use administration problem 7.1.4. Lack of maintenance
7.1.5. Lack of operational skill/training vi. Others………..
8. Reliability (dependability) of irrigation water supply (in terms of flow rates and duration of supply).
8.1.Flow Rate 8.1.1.Good 8.1.2.Medium 8.1.3.Bad 8.1.4.Very bad
8.2.Duration of supply 8.2.1.Good 8.2.2. Medium 8.2.3.Bad 8.2.4.Very bad
9. Is the distribution fair? 9.1.Veryfair 9.2.Fair 9.3.Unfair 9.4.Very frustrating
9.3. If unfair, why is it so (explain) 9.3.1.Head users 9.3.2.Corruptedofficials/WUA 9.3.3.Illegal water users
9.3.4. Non-reliability of the water sources 9.3.5.Others explain______________________________
10. Dependability of the water deliveries to get water on arranged irrigation turns?
Good Medium Bad Very bad
10.1. If the delivery is bad/very bad, explain why it is so?
10.1.1 Poorly functioning irrigation infrastructure
10.1.2. Illegal water users Weakly organized water delivery services 10.1.3. Non-reliability of the water sources
10.1.4.Other,specify_____________________________
10.2. Do you have adjustable flow control mechanism at your farm inlet to regulate water flow to your field? yes No

10.2.1. If yes, what types of measuring equipments are used?
____
11.What are the criteria farmers used to scheduling irrigation? (Rank in order according to the priority).
11.1.Water supply availability 11.2. Fixed time periods 11.3. Condition of the plant
11.4.Other specify____
12. Who manages and control the irrigation water?
12.1. The community as a whole
12.2.Representatives of the community
12.3.Kebele administrators
12.4.Others (Specify): ____
13.Is there any conflict?
13.1. If yes, what do you think is/are the common source(s) of conflicts?
13.1.1.Water shortage
13.1.2.Land shortage
13.1. 3.Water theft
13.1.4. Water management (unfair distribution)
13.1.5. Others (specify):____
14. Is water equally available to all users in the scheme?
Yes No
15. Is there problem of water theft or unauthorized canal breaching?
Yes No
16. Do you foresee any conflict on the water use in the future?
Yes No
17. If yes, what will be the causes? ____
18. What should be done to avoid the conflict? ______________________________________

D. Organizations

1. Is there water users association in your locality?
Yes No
1.1. If yes, are you a member of water users association?
Yes No
1.2. If yes, how was the association formed?____
1.3. If you are the member of WUAs, what benefits do you get from being a member?
1.3.1. Irrigation water on program basis
1.3.2. Economic water use
1.3.3. Adapt social accountability and responsibility
1.3.4. All
1.4. As a member of WUA what is your contribution for the sustenance of the scheme?
1.4.1. Cost sharing
1.4.2. Labor contribution
1.4.3 Others

1.5. Generally, how do you perceive the overall contribution of WUA to the scheme functioning and sustenance?
1.5.1. It has positive contribution
1.5.2. No contribution at all
1.5.3. Not known
1.6. Do you think your WUAs strong?
Yes No

E. Institutional supports

1. Access to improved technology for agricultural production
1.1. Do you have access to different input supply for irrigation?
Yes No
1.2. Did you use improved seed, fertilizer, chemicals and hand tools?
Yes No
1.3. If yes, explain improved technology use in the year 2011E.C__________________________
1.4. Do you use agricultural inputs as per the recommended rate?

Yes No

1.5. Do you have responsible institution that supply input for irrigation farming as per the schedule of your irrigation practice?

Yes No

F. Sustainability of the Scheme

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

Yes No

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

2.1. to the community

2.2. to the government

2.3. to the NGOs

2.4. any combination of the above

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

Yes No

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

4.1. It is not my responsibility

4.2. I do not know how to do it

*4.3 Others (specify)*____