ASSESSING FARM WATER MANAGEMENT AND INFRASTRUCTURAL PERFORMANCE OF KOGA IRRIGATION SCHEME; IN THE CASE OF INGUTI UNITE

**MSc.THESIS**

**BY**

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# ASSESSING FARM WATER MANAGEMENT AND INFRASTRUCTURAL PERFORMANCE OF KOGA IRRIGATION SCHEME; IN THE CASE OF INGUTI UNITE IN NORTH MECHA WORDA, AHMARA REGINAL STAT, ETHIOPIA

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A THESIS SUBMITTED TO THE DEPARTMENT OF WATERRESOURCE AND IRRIGATION ENGINEERING, FACULTY OF BIOSYSTEMS AND WATER RESOURCE ENGINEERING,SCHOOL OF GRADUATE STUDIESHAWASSA UNIVERSITYHAWASSA, ETHIOPIA

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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 WUBLIKER NEGESE YIHUNEentitled " Assessing Farm Water Management and Infrastructural Performance of Koga Irrigation Scheme; In The Case of Inguti Unite in North MechaWoreda, Amhara Regional Stat, Ethiopia", and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in water resource engineering and Irrigation.

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## DECLARATION

I, Wubliker Negese declare that this thesis is my own original work and it is not submitted to any other institution anywhere for the award of any academic degree and diploma. This thesis has been submitted in partial fulfillment of the requirements for MSc degree at HAWASSA University. I declare that this thesis is my own work and that all sources of materials used for this thesis have been duly acknowledged referenced all materials used in this work.

Name of the student ______________________________Signature::_____________

Place: Institute of Technology, Hawassa University, Hawassa

Date of Submission: ________________________

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## LIST OF ABRIVATION

| | |
|---|---|
| BD | Bulk Density |
| CAR | Cropped Area Ratio |
| C L | Conveyance Loss |
| DA | Development agents |
| ETC | Crop water requirement |
| Ea | Field Application efficiency |
| Ec | Conveyance Efficiency |
| Et | Overall scheme efficiency |
| ETo | Reference crop Evapotranspiration |
| FAO | Food and agricultural Organization |
| FC | Field Capacity |
| FWM | Farm water management |
| GDP | Gross domestic product |
| GOs | Governmental organizations |
| Ha | Hectare |
| HHs | Households survey |
| ICID | International conference of Irrigation and Drainage |
| IO | Irrigation Organizations |

| | |
|---|---|
| ITCZ | Inter tropical convergence zone |
| IWMI | International Water Management Institute |
| IWRM | Integrated water resource management |
| Kc | Crop coefficient |
| Ky | Yield response factor |
| M.A.S.L | Meter above sea level |
| MoA | Ministry of agriculture |
| MoFA | Ministry of food and agriculture |
| MoWRI | Ministry of water resources and irrigation |
| MoWR | Ministry of water resources |
| NGOs | Nongovernmental organizations |
| OCR | Overall consumed ratio |
| OFWM | On farm water management |
| PWP | Permanent Welting Point |
| SC | Secondary canal |
| St | Storage efficiency |
| TC | Tertiary canal |
| WUA | Water Users Association |

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# ABSTRACT

Irrigation scheme performance was assessed to evaluate the field water managements and its infrastructural performance .The principal objective of this study was to evaluate field water management and infrastructural performance of Koga irrigation scheme specifically Inguti unit using selected internal performance indicators. Moreover, an institutional support service was evaluated to understand how the scheme is being administered. Field data such as discharge, soil moisture content, and soil physical properties and infrastructures performance were collected. Field surveys and group discussions among the farmers/beneficiaries and Water User Associations (WUA) was also conducted to evaluated existing situation of the support service in the scheme and its performance of WUA. From house hold survey 493 users55 beneficiaries were selected by stratified random sampling. Field surveys and group discussions among the farmers/beneficiaries and Water User Associations (WUA) was also conducted to evaluated existing situation of the support service in the scheme and its performance of WUA. From house hold survey 493 users55 beneficiaries were selected by stratified random sampling. Secondary data such as crop data, climate data and design documents were collected from National Meteorological agency and Koga Irrigation Project office. CROPWAT 8.0 model, GIS and Microsoft office (excel and word) were used for data analysis and documentation in this thesis. Average conveyance efficiency values ranged from 81 to 86.5% for lined (secondary and tertiary canals) and about 64% for unlined tertiary canals. The maximum water loss observed was 0.19 and 0.21l/s/m on lined (secondary and tertiary) canals respectively. And also the maximum water loss observed in unlined tertiary canals was 0.26l/s/m. The average field storage efficiency was found to be 78.9 % and the average field water application efficiency was 53.5%. Average values of the scheme water level ratio, cropped area ratio and infrastructural effectiveness was 85.8%, 94% and 96.2% respectively. The performance of the irrigation scheme was weak due to poor field water managements as indicated above. This might be attributed due to a number of factors observed at field such as illegal water abstraction, unequal distribution of irrigation water, sedimentation of canals and inadequate operation and canal maintenance. Field survey indicates sedimentation, cracking and weeds problems in the lined canals. The overall efficiency of scheme in the Inguti unit was found to be 46.3%. This implies organizational set up and legal enforcement of bylaws and institutional support service was weak to fully maintained and managed irrigation water in the fields.

**Key words**: Koga Irrigation scheme, Infrastructural performance, Water User Association

# CHAPTER ONE

## 1.1. Introduction

Agriculture remains the basis of Ethiopia's economy employing 85% of the population and contributing to 45% of the GDP (Awulachew et al., 2010). The majority of the population has a subsistence mode of crop and livestock production. Despite its economic and social benefits, production and productivity of different agricultural crops in Ethiopia is mostly on a small scale and average crop yield is very low, as compared to other developing countries (Awulachew et al. 2010; Kalkidan et al., 2016).

The majority of Ethiopian population is dependent on rain fed agricultural. However, estimated crop production is not close to fulfill the food requirements of the country. One of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development (Robel,2005). To meet the demand of the ever-growing population, increase in agricultural production and productivity, which largely depends on water availability is of paramount importance to the country. Irrigation development is essential to inspire the economic growth and rural development, and it is considered as a foundation of food security and poverty reduction in Ethiopia. Irrigation is one means by which agricultural production can be increased to meet the growing food demands in the country (Awulachew et al., 2005).

Water is an irreplaceable resource used for numerous economic, social, spiritual, and representative purposes, on which the existence of life depends (Sehring and Diebold 2012). Water is also an essential resource for irrigated agriculture; there by water users should optimize water use efficiency by applying basic information about irrigation systems, crop water use and management practices. Irrigation can be defined as an artificial application of water to soil for the purpose of supplying the moisture essential in the plant root zoon to prevent stress that may cause reduced yield and/or poor quality of harvest of crops (Kumar et al., 2010).

Efficient and effective utilization of irrigation water has been major challenge in irrigation schemes. Efficient and adequate dosage of irrigation water advances crop production and raises water use efficiency for future purposes (Taddesse and Peden 2001). The assessment of irrigation performance is defined as the documentation of observations made on the irrigation activities and analysis for the purpose of improving the irrigated agriculture ( Bos et al., 2005).

Performance evaluation of an irrigation scheme also defined as the systematic observation, documentation, and interpretation of activities related to irrigated agriculture with the objective of continuous improvement helps for irrigation management to execute and continuously observe and assess the effectiveness of water delivery activities (Zwart and Leclert, 2010), Bos et al. (2005).Performance evaluation of irrigation infrastructure is a practical tool to assess and evaluate the successes/failures of irrigation schemes familiar with its managements and well performs at the scheme to meet growing challenges; increasing demand for irrigation to meet the growing food demands of the population: the competition for water allocation from high priority non-agricultural sectors and technical infeasibility (Yusuf, K. and Tena, A. (2006).

The main aim of performance evaluation and irrigation water management are to keep the water level at the root zone and assess its effectiveness of irrigation infrastructures within a range where crop yield and quality are not damaged due to either inadequate or excess water (Geremew et al. 2008).and also Performance evaluation is carried out for the purpose of improving system management (Small and Svendsen 1990).Therefore, optimum irrigation water uses, appropriate allocation of irrigation water, appropriate operation of irrigation structure, regularly follow up and maintenance of irrigation infrastructures are energetic for durability of cultivation in water scarce areas and irrigation sustainability (Ashraf et al. 2007; Khalkheili and Zamani 2009).

Performance evaluation is carried out for such purposes as improving system management, determining the overall performance of the system and the elements which cause trouble to the system (Molden et al., 1998).However, efficient operation and management of an irrigation system plays an important role in the sustainability of irrigated agriculture (Mishra et al., 2001).

Performance evaluation of the irrigation scheme is paramount roles for effectiveness of irrigation structures and managements not only to point out where the problem lies, but also to identify alternative management options that may be effective and feasible in improving irrigation scheme performance. Therefore, the overall objective of the study was evaluating the infrastructural performance and assessing field water managements of Koga irrigation scheme in Inguti irrigation scheme using selected internal indicators.

The structured system in an irrigation project is the management of water distribution with regulated flow at the upper canal networks and a proportional division of water at the lower level canals based on a systematic operational plan. The irrigation water flow in lower level canals is maintained either at full supply level or at no flow condition for fixed days on a rotating interval. The system is equipped with water control gates at the upper canal networks up to the service area (Albinson and Perry, 2002)

According to this principle; upper level canals would run with continuous flow while lower level canals would run with intermittent water supply. The structured system in irrigation scheme has different levels (stag I, stage-II and stage-III). In irrigation infrastructure including, the main and secondary canals constitute the upper canal network, while the sub-secondary and or tertiary canals down to the watercourse form the service area of the structured irrigation system. The underlying assumption of structured irrigation system is to distribute water equitably according to the command areas effectively and efficiently (Shanan, 1986).

One of the advantages of a structured system is its transparency and simplicity in water entitlement (Albinson and Perry, 2002). Moreover, a structured system assures reliability of water supply and easier management through ungated regulating structures. It is equally important to understand the hydraulic characteristics of water division structures by all the concerned stakeholders and to craft faithful rules and regulations for maintaining equity (Shanan, 1986)

Irrigation schemes infrastructures face various problems related to operation ,maintenance, water management and sustainability, that have greatly reduced their benefits and challenged their overall sustainability irrigations , so as need arises to identify which institutional arrangement for water management in community managed irrigation schemes is better functions( Zeleke et al., (2015). Performance evaluation of irrigation schemes is assessed for several reasons. It can be to improve scheme operations, to evaluate progress against strategic goals, as integral part of performance-oriented management, to assess the status of irrigation scheme, to assess the health of a scheme, to better understand determinants of performance, to identify constraints and to compare the performance of a scheme with others or with the same scheme over time (Molden et al., 1998).

Koga irrigation scheme highly benefited the farmers in the scheme to harvest twice per year by supplying irrigation access with full infrastructures. However, due to lack of awareness and frequent training bout irrigation water application and managements, farmers' irrigation management is poor and with severs water wastage. The water distribution approach in the scheme is fixed rotational water delivery scheduling, yet, the water control and regulating structures vary from field to field vies some use water control structures while others use local water control mechanisms like mud and stone.

Assessment of the performance of infrastructural performances through maintenance requirement by administrative of the scheme becomes vital to ensure well functioning of the irrigation scheme. Therefore, this study was conducted to assess the infrastructural and managerial performances of Koga irrigation scheme in Inguti unite using performance indicators.

## 1.2. Problem statement

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).

Koga irrigation project is designed to irrigate around 7000 ha with in 12 units/blocks to enhance crop production and sustainable food satisfaction. However, only around 6,000 ha of land are currently under irrigation while the remaining 1000ha land is out of production due to shortage of water. The remaining un-irrigable land affects the aim of the project and the community. The cause of underperformance of Koga irrigation scheme is practically unknown in related to its scheme infrastructural performance and water managements. Since the scheme is established to alleviate poverty and improve the livelihoods of the communities, assessment of structural performance of the scheme is important to determine the causes of deficient.

The infrastructural problems in canals are frequently associated with weak management which results in poor conveyance efficiency. The major problem of canal efficiency in the scheme is the conveyance of water release from the diversion weir to farm due to several factors. This could be one of the reasons for unfair and insufficient distribution of water among the users through different level of canal structures. The types of irrigation methods the farmers practice are not well defined. However, the schemes have not been well perform and fully functional as expected objectives and their performances.

The irrigation system infrastructures in the scheme lacks the full capacity to deliver irrigation water, has problems of maintenance, some administrative gaps, poor water management, siltation, flooding and erosion, seepage loss, cracking, weed, sedimentation, scoring are the most problems that occur in conveyance structures which reduce the efficiency of water deliveries and water uses where exist in the study area. It is increasingly being recognized that poor performance is not only consequences of technical performance in structural design and construction, but it is institutional and managerial problems tended to be more common constraints to the success and effectiveness of irrigation schemes in the study area. Here Koga irrigation scheme the major portion of the excess diverted water that was lost on farm and lack of institutions, which can enforce the proper uses of irrigation waters on off farm level (off take gate) and on farm levels (filed water) this might be affects its performance of the schemes in relation to field water managements and institutional support service.

## 1.3. Objective

### 1.3.1. General Objective

The general objective of the study was assessing the farm water management and infrastructural performance evaluations of Koga irrigation scheme in the case of Inguti unit**.**

### 1.3.2. Specific Objective

- To evaluate infrastructural performance of canal structures at tertiary level
- To asses and evaluate canal efficiency
- To assess and evaluate field irrigation application efficiency
- To analyze the institutional arrangement and relationships with overall 'performance' of WUA.

## 1.4. Research Questions

- What is the level of infrastructural performance of canal structures at the unit?
- Does the water delivery performance in the canal efficient?
- What are the challenges and opportunities for irrigation efficiency?
- Do managerial and institutional issues affect the sustainability of schemes?

## 1.5. Significant of the study

The role of assessing the performances irrigation infrastructures and field water managements is to identify managerial practices and systems that configure for the effectiveness of irrigation infrastructures that can be feasibly and efficiently implemented, installed and designs of the scheme to improve irrigation application efficiency. Evaluating infrastructural performances of the schemes provide reliable and new valid insights that efficiently operated and maintained irrigation infrastructures at tertiary level of the study unite.

Assessing managerial issues of irrigation scheme in Inguti unit is also vital to identify system of managements to operate its schemes and provide immediate maintenances to solve the issues which are improving the functionality of irrigation structures. The performances evaluations of the scheme described in this paper have key role to play as we address the future system management in the study area. And also will give information for further improvement and investment approaches for different stakeholders.

# CHAPTER TWO

# 2. LITERATURE REVIEW

## 2.1. Concepts of Irrigation and practices

A technique that involves artificially providing water to crops enables them to grow. This technique is used in farming to enable plants to grow when there is not enough rain, particularly in arid areas. It is also used in less arid regions to provide plants with the water they need when seed setting. When using irrigation due to insufficiency of rainfall to allow crop to grow, irrigation is said to be supplementary; which is the process of distribution of additional water to the crop with the objective of stabilizing and increasing yield, in environments where the given crop is usually grown under rain fed agriculture. In arid and semi arid areas, irrigation is used for production during the dry season in the absence of rain; in that case irrigation is said full. Related to full irrigation, one can use sometime deficit irrigation to save water (Water Report 22: Deficit Irrigation Practices, FAO)

Irrigation is the reliable method of increasing agricultural production and productivity and has greater impacts in solving food security problems in many parts of Ethiopia. Realizing its importance for food production, the country has been allocating huge investments for irrigation infrastructure development over the last two decades (Abate, 1994). This investment, together with improved crop production technologies has enabled the country to move towards achieving self-sufficiency in food production. Nevertheless there is also an issue in which many irrigation schemes do not perform according to the design expectations (Checkol and Alamirew, 2008). Towards solving such issues, performance evaluation studies and management of the application of water to irrigable land should be important within a given irrigation scheme for achieving more benefits. In this regard irrigation performance includes the result of variety of activities such as planning, design & construction, operation of facilities, maintenance and application of water to the land. Basically issues of the application of the right amount of water to the land at the right time are more common in various irrigation schemes available in Ethiopia (Hagos et al., 2009), which requires local solutions.

## 2.2. Irrigation Development in Ethiopia

Irrigation development in Ethiopia can be seen as a key factor in the food security and poverty reduction tool because it has the potential to stimulate economic growth and rural development (Hagos et al., 2009). This shows that irrigation infrastructure is increasing year by year with broad positive impacts and experiences in small and large irrigation projects. In Ethiopia, the size of the farm per household is 0.5 ha and the irrigated land per household ranges from 0.25 ha to 0.5 ha in the Ethiopian context (MoA, 2011a). As a result, individual land holdings for each household are very small for family food. On the other hand, irrigation development in Ethiopia is in its early stages (MoA, 2011a). The Ethiopian government is pursuing plans and programs for irrigation development in an effort to significantly reduce poverty and create an environment for social change. As a result, the average rate of irrigation development in Ethiopia over the past 12 years was about 1,090-1,150 ha / year (Asmelash et al., 2007); (Gebre-Selassie et al., 2012).

Irrigation develops rapidly; however, its contribution to the national economy is not important when compared to rain fed agriculture (Haile & Kasa, 2015). Irrigation development helps to increase household income and reduces the incidence of poverty at the household level. It can benefit the poor through raising yields and production and non-farm employment (Eneyew et al., 2014). Poverty eradication and food security are among the priority concerns of the government in Ethiopia. As a result, irrigation development is taking place through the use of government budgets, donor programs and NGOs. However, as compared to its potential and rain-fed farming, contribution of irrigation to the national economy is quite limited which contributes about 2.5% of the overall GDP (Hagos et al., 2009); MoA, 2011a). Modern small-scale irrigation development and management started in the 1970s initiated by the Ministry of Agriculture (MoA) in response to major droughts, which caused widespread crop failures and food insecurity( Teshome, 2006).Small-scale irrigations playing an important role in adapting to climate change, achieving food security, and improving household incomes (Douxchamps et al., 2015)

Modern water development schemes are a relatively new phenomenon in the country. The Imperial government took the first initiatives in water resource development in the second half of the 1950s. Large scale water projects for agricultural purposes and power generation were constructed from the end of the 1950s, and were concentrated in the awash valley as part of the agro-industrial enterprises that were expanding in the area at that time. They subsequently spread to the Rift valley and the Wabe Shebelli basin. Essentially, the government's interest at that time centered almost entirely on large-scale and high technology water projects: hydro-power dams, irrigation schemes and water supply projects for Addis Ababa and a few major towns. From 1974 to 1991, no large scale private capital investment was committed as a result of the prohibition of private land ownership or rental of land on commercial scale by the land reform proclamation of 1975 as per the then socialist policy adopted by the Government. During this period public capital expenditure concentrated on the development of state farms and producer cooperatives which contributed for less than 10 percent of the total production during that period (Fekadu et al., 2000).

The Military Government nationalized the rural lands and commercial farms, and changed the existing commercial farms together with newly established farms (mainly rain fed farms), into state owned enterprises. It was considered as a way out to address the problem of food self insufficiency and to earn foreign currency. Consequently, commercial farm development during this regime was practically nonexistent. On the other hand, development of small scale irrigation was encouraged to be effected by the local farmers to cope with recurrent droughts (Fekadu et al., 2000).Currently; the government is giving more emphasis to irrigation sector by way of enhancing the food security situation in the country. Efforts are being made to involve farmers progressively in various aspects of management of small-scale irrigation systems, starting from planning, implementation and management aspects, particularly, in water distribution, operation and maintenance to improve the performance of irrigated agriculture.

## 2.3. Concept of performances and Performance evaluation

Abernethy (1986) describes the concept of performance is the degree to which a system achieves its objectives; the performance of a system represented by its measured levels of achievement in terms of one or several parameters. The performance of any irrigation system is defined as the measurement the degree to which it achieves anticipated objectivity, therefore it is important to measure and evaluate their success or failure of objectively and identifies specific areas in need of improvement (Cakmak et al., (2004). Murray-Rust and Snellen (1993) improve the concept of performance;

performance of a system as encompassing the totality of both its activity inputs and the transformation of the inputs into intermediate and final outputs, and the effect of these activities on the system itself and on its external environment.

Performance evaluation of an irrigation scheme also defined as the systematic observation, documentation, and interpretation of activities related to irrigated agriculture with the objective of continuous improvement helps for irrigation management to execute and continuously observe and assess the effectiveness of water delivery activities (Zwart and Leclert, 2010), Bos et al. (2005).Performance evaluation of irrigation infrastructure is a practical tool to assess and evaluate the successes/failures of irrigation schemes familiar with its managements and well performs at the scheme to meet growing challenges; increasing demand for irrigation to meet the growing food demands of the population: the competition for water allocation from high priority non-agricultural sectors and technical infeasibility (Yusuf, K. and Tena, A. (2006).

### 2.3.1. Performance assessment approaches

As Sajjad Ahmad (2012) irrigation system performance includes efficiencies of various components like storage efficiency, conveyance efficiency of canals, application efficiency, and field efficiency among others. In turn, three main standards could be used to evaluate the performance of irrigation systems, these are: the physical condition of the infrastructure, water delivery services, and agricultural production. Bos et al., (2005) describes the purpose of performance assessment is to achieve efficient and effective irrigation performance by providing related feedback to management at all levels.

Performance assessment is key factor to improve daily operation, to identify problems and monitor the effect of interventions to solve these problems. With scarce water resources, the need for better performance of irrigation became obvious. For an effective performance assessment program a framework needs to be defined Gorantiwar & Smout (2005). It is helpful to consider an irrigation system in the context of nested systems to describe different types, uses of performance indicators and address the important question of boundaries within which performance is assessed Small and Svendsen (1992). The performance of irrigation water delivery systems and performance of irrigated agriculture systems relies on the water conveyed by specific set of canals (Korkmaz and Avci (2012).

Molden and Gates (1990) and Bos et al., (2005) have tried to standardize performance indicators to permit better comparison of irrigation systems. To assess the performance it is important to confirm the indicators selected in respect to the objectives established for that irrigation system. A good indicator tells a manager what current performance of the system is, and, in combination with other indicators, may help to identify the correct course of action to improve performance within that system.

### 2.3.2. Irrigation Performance Assessment

Performance of an irrigation system is represented by its measured levels of achievement in terms of one or several parameters that are chosen as indicators of the system's goals ( Styles & Marino,2002). The cause of the poor irrigation performance has been blamed on technical, financial, managerial, social, and/or institutional causes. Performance assessment is an activity that supports the planning and implementation process. The ultimate purpose of performance assessment is to achieve an efficient and effective use of resources by providing relevant feedback to the project management at all levels (Dong et al., 2004).

Molden et al., (1998) stated that 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.

### 2.3.3. Purpose of Irrigation Performance Evaluation

The evaluation of the irrigation scheme performance is of paramount importance not only to point out where the problem lies, but also to identify alternative management options that may be effective and feasible in improving irrigation Scheme performance ( Teshome et al ., 2018). Many scholars emphasized the importance of performance evaluation for an irrigation system. Much of the work to date in irrigation performance assessment has been focused on both external and internal processes of irrigation systems. These process indicators relate performance to management targets such as timing, duration, and flow rate of water, area irrigated and cropping patterns. (Kloezen, 1998), stated that effective irrigation management requires reliable performance assessment.

Performance evaluation is basically to ensure all activities proceed smoothly as planned towards achieving those objectives and that system managers are alerted easily to potential threats to crop and production system performances and react in time to avoid or overcome the situation when it occurs. Specially, some of the major roles of performance assessment and evaluation are to ensure that the cropping intensity targets met, for accurate supply demand matching, water savings and to alert potential crisis event. Walker, (1989) stated that the principal objective of evaluating surface irrigation systems is to identify management practices and system configurations that can be feasibly and effectively implemented to improve the irrigation efficiency. An evaluation may show that higher efficiencies are possible by reducing the duration of the inflow to an interval required to apply the depth that would refill the root zone soil moisture deficit. The evaluation may also show opportunities for improving performance through changes in the field size and topography.

Evaluations are useful in a number of analyses and operations, particularly those that are essential to improve management and control. Evaluation data can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year. The surface irrigation system is a complex and dynamic hydrologic system and, thus, the evaluation processes are important to optimize the use of water resources in this system

## 2.4. CROPWAT model

CROPWAT model is a computer program for irrigation planning and management, developed based on the FAO Penman-monteith method (Smith, 1992). Its basic function includes the calculation of reference evapotranspiration, crop water requirement and crop and scheme irrigation requirement. Moreover, the software provides options for the design of diverse water supply scenarios and the computation of a number of water supplies for several crop patterns (Allen et al., 1998). Normally, the computation of crop water requirement and irrigation schedules in CROPWAT is based on the required information prepared by the user which whether can be directly typed into the software or uploaded from other sources.

## 2.5. Crop and Irrigation water requirement of the crop

Crop water requirements and crop irrigation requirements can be carried out from basic information from the crops selected and should include, average planting date and average harvesting date (FAO, 1996). Standard information on crop coefficient, rooting depth, depletion level and yield response factors, and length of individual growth stages are also needed. The water requirements are different from one crop to another. Although growing crops are continuously using water, the rate of water use depends on (1) the kind of crop, (2) the degree of maturity and (3) atmospheric condition, such as radiation, temperature, wind, and humidity. The rate of growth at different soil water contents varies with different soils and crops. During early stages of growth the water needs are generally low, but they increase rapidly during the maximum growing period to the fruiting stage. During the later stages of maturity, water use decreases as the crops ripen (Schwab et al., 1995).

The crop water requirement is designed as ET crop and is expressed in millimeters per day (mm/day) (FAO, 1998). Direct measurements of procedures are laborious and time-consuming. Consequently a large number of estimation methods have been developed. The four most widely known and used are the Blaney-criddle, Radiation, Penman and Pan Evaporation methods. Among them the Penman method recently further refined as modified FAO Penman Monteith method is best for mean estimates over short periods of about 10 days (FAO, 1998).

Calculation of water and irrigation requirements utilizes input of climatic, crop and rainfall data. The climatic input data required are reference evapotranspiration(monthly/decade) and rainfall (monthly, decade/daily). The crop parameters used for estimation of the crop evapotranspiration, water balance calculations, and yield reduction due to stress include; crop coefficient, Kc, length of growing season, critical depletion level, p, and yield response factor, KY. In short, the crop water requirement (crop evapotranspiration, ETc) is calculated by multiplying the reference evapotranspiration, ETo, by corresponding crop coefficient, Kc equation (2.1).

$$ETC = ETo * Kc \qquad (2.1)$$

The reference crop evapotranspiration value, ETo, is defined as the rate of evapotranspiration from an extended surface of 8 to 15 cm tall green grass cover of uniform height, actively growing, completely shading the ground and not short of water (FAO, 1980).

## 2.5.1. Effective rainfall

Effective rain fail for field crops is the portion of rain fail which is useful directly or indirectly for crop production at the site where it fails (dastan, 1974).Effective rainfall estimates are also important for planning cropping sequences in both dry-land and irrigation crop production. Rainfall that runs off the soil surface or passes through the root zone does not contribute to crop growth and yield. Factors that influence effective rainfall are slope, soil texture and structure, plant cover or crop residue and storm intensity and duration (Tsai & Yang, 2006). There are various approaches that can be used to estimate the effective rainfall from the total monthly rain fall. However, the following formula was developed by FAO based on analysis carried out for different arid and semi humid climates and more sustainable for Ethiopian.

$Pe = 0.6 \times Pdep - 10$ for $pdep < 70mm$ … … … … … … … . . . … … … … … 2.3

$Pe = 0.8 \times Pdep - 24$ for $pdep > 70mm$ … … … … … … … … … … …. … … … 2.4

Where: Pe - Monthly effective rain fall (mm), Pdep - Monthly dependable rain fall (mm)

## 2.5. 2. Irrigation Scheduling

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

FAO (1989) explained that when surface irrigation methods are used, it is not very practical to vary the irrigation depth and frequency too much. In surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all the time. Therefore, it is often important to estimate the irrigation schedule and to fix the most suitable depth and interval to keep the irrigation depth and the interval constant over the growing season. Irrigation scheduling should be based on avoiding water deficit during the period of stolonization and tuber initiation and yield formation. Supply of water can be restricted during the early vegetative and ripening periods. Savings can also be attained by allowing higher soil water depletion toward the ripening period so that all available stored water in the root zone is used by the crop. This practice may also hasten maturity. Correct timing of irrigation may save irrigation applications including the last irrigation prior to harvest.

## 2.6. Soil Water Availability

Soil water availability refers to the capacity of the soil to return water available to plants. After heavy rain or irrigation, the soil will drain until field capacity is reached. Field capacity is the amount of water that a well- drained soil should hold against gravitational forces, or the amount of water remaining when downward drainage has markedly decreased. Irrigation interval depends on water depletion requirement of the crop, rooting depth, soil type and growth stage of the crop. The total available water (TAW) is the difference between field capacity and wilting point contents multiplied by the depth of the root zone (Zr), (Allen, et al., 1998). Only a portion of the total soil water is readily available for plant use. Plants can only extract a portion of the stored water without being stressed. An availability coefficient is used to calculate the percentage of water that is readily available to the plant.

## 2.7. Performance Evaluation Indicators for Irrigation Water use Efficiency

The term efficiency is very often used to express irrigation systems performance (Zhang et al ., 1999). It is commonly applied to each irrigation sub-system: storage, conveyance, distribution off and on-farm application sub-systems. The performance of a system can be defined as its efficiency, understood as the relation between actual results versus the expected results of the system (inputs and outputs). Low level of performance can be identified at any level and stage of irrigation systems. At system level, the status of cropping intensity and yields from many irrigated areas are usually unsatisfactory. These low performances occur in irrigation though it is a technological package that feeds billions of people. Good performance is not only a matter of high output, but also one of efficient use of available resources (Murray-Rust & Snellen, 1993).

Improper irrigation practices lead to inefficient water distribution, non uniform crop growth, and excess leaching in some areas and insufficient leaching in others, all of which decrease the yield per unit of land area against per unit of water applied (Strelkoff et al ., 1999). Evaluation of performance of irrigation systems has been increasingly stressed in recent years by many researchers and managers of irrigation schemes. In the field of irrigation system management, performance evaluation of irrigation system is the key issue (Seleshi et al., 2010). The performance of a system can be defined as its efficiency, understood as the relation between actual results versus the expected results of the system (inputs and outputs). According to Svendsen & Small, (1990), there exist three categories of performance measures: process measures, output measures and impact measures. The first category refers to the systems internal operations, such as policies, organizational and communicative processes.

The second one, output measures, is used to evaluate irrigation services delivered to farmers, of essential importance given its impact on agricultural production and therefore on farmers‟ revenue (system's final output). Last category brings up the evaluation of the effects of system's outputs in a larger scale, in the social, economic and environmental dimensions. New approaches for assassin new‟ irrigation systems with multi-criteria performances call for new indicators to (Le Grusse et al., 2009). According to FAO, (2003), six ways to improving irrigation efficiency are; 1. Reduce seepage losses in channels by lining them or using closed conduits. 2. Reduce evaporation by avoiding mid-day irrigation and using under canopy rather than over head sprinkling, and avoid over irrigation 3. Control weeds on inter-row strips and keep them dry 4. Plant and harvest at optimal times; and 5. Irrigate frequently with just the right amount of water to avoid crop distress. But due to declining performance of many large-scale irrigation schemes, interest has been developing in recent years for seeking way to improve the productivity and livelihoods of the world's small-scale farmers who typically cultivate less than five hectares of land (Purcell, 1997). Lack of knowledge and tools used to assess the performance of projects adds to the problem (Mintesinot et al., 2005). Irrigation performance indicators cover the traditional aspects related to adequacy, equity and reliability of the water service (Murray-Rust & Snellen, 1993). Bos, (1997), after reviewing significant work, suggested a list of indicators being related to the performance of (i) The water delivery system, (ii) the environment and (iii) The irrigated agricultural economic system.

### 2.7.1. Farm water management

Most on-farm water management (OFWM) problems are not new. They have been a threat to agriculture in many countries around the globe in the last few decades. However, these problems have now grown larger and there is increasing public demand for the development and management of land and water to be ecologically sustainable as well as economic. As there is a close interrelationship between land use and water resources, farmers need to be aware of this interrelationship and adjust their OFWM efforts in order to address the issues. In their management efforts they need to consider both the on-site and the off-site effects (Wolff and Stein, 1999)

Water management can be defined as the planned development, distribution and use of water resources in accordance with predetermined objectives while respecting both the quantity and quality of the water resources. It is the specific control of all human interventions concerning surface and subterranean water. Every planning activity relating to water can be considered as water management in the broadest sense of the term (International Commission on Irrigation and Drainage (ICID), 2000)

Traditional management practices of the irrigation supply and conveyance systems often contribute to high water losses. On many farms, the low irrigation efficiency is further accentuated by farmers' traditional irrigation methods and practices, inadequate land leveling, lack of a crop-specific water application, insufficient drainage, and poor maintenance of irrigation and drainage infrastructure.

Water management can be defined as the planned development, distribution and use of water resources in accordance with predetermined objectives while respecting both the quantity and quality of the water resources. It is the specific control of all human interventions concerning surface and subterranean water. Every planning activity relating to water can be considered as water management in the broadest sense of the term (ICID), 2000). Therefore, OFWM can be defined as the manipulation of water within the borders of an individual farm, a farming plot or field. For example, in canal irrigation systems, OFWM starts at the farm gate and ends at the disposal point of the drainage water to a public watercourse, open drain or sink. OFWM generally seeks to optimize soil water-plant relationships in order to achieve a yield of desired products. The managers (farmers) usually try to achieve this desired yield by minimizing inputs and maximizing outputs, so as to optimize profits. In order to accomplish this, water has to be managed skillfully through certain practices covering areas of: soil and water conservation, water application, drainage, soil amelioration, and agronomy. All this has to be done within the context of the socio-economic environment of the community and the farmer's personal situation. There are a range of tools available that enable the manager (farmer) to apply these practices (Wolff and Stein, 1999)

## A. Field Application Efficiency

Water application efficiency is a measure of how effective the irrigation system is in storing water in the root zone of the grain. There is a general indication of how well an irrigation system does its main job of delivering water from the production system to the harvest. The aim is to raise the water and store it in the root zone to meet the water needs of the plants (Irmak et al., 2011). Rogers et al., (1997) methods for determining the application efficiency of a particular irrigation system are generally time-consuming and often difficult, as they may change over time due to changing soil, crop and climatic conditions. A very common measure of agricultural irrigation efficiency is application efficiency. The application efficiency does not indicate whether the crop has been irrigated. Roger et al., (1997) it is possible to have high application efficiency, and 50-90% can be used for the general system type comparison. FAO (1989) reported that the USA's achievable application efficiency (SCS) is 55-70%, while in ICID / ILRI this value is about 57%. Adriani et al., (2011) stated that it could be in the range of 50-80%, and up to 80% in a well-managed system.

In general, according to Michael (1997), application efficiency decreases as the amount of water applied each irrigation increases. Field irrigation efficiency is influenced by factors such as soil type, field application methods, application depth and climate. Very high values are achieved in arid climates and where water shortage prevails (Walters and Prizavyevich, 1991). Kenneth, (1988) pointed out that the efficiency of water use can be greatly varied with irrigation system, type and management, and suggested that the application efficiency which can be achieved for surface irrigation is in the range of 80-90%, 70-85% and 60-75% under basin, border and furrow type of system respectively.

## B. Irrigation water-use efficiency

Within many irrigated areas, water is an increasingly scarce resource. Hence, it is logical to assess the productivity of irrigation in terms of this scarce resource (Kijneet al., 2003). Such an assessment can be made from a variety of viewpoints. The most common are: the productivity in terms of actual evapo-transpiration (Etc) and in terms of the volume of water applied during the cropping period. Irrigation water-use efficiency (IWUE), also called irrigation water productivity, is defined as the ratio between crop production and the amount of water applied to the crop (Bos et al., 2005; Kijne et al., 2003)

The yield of the harvested crop equals the unit yield (kg/ha) times the considered area (ha). If viewed from the farmer's perspective, the volume of supplied water is measured either at the farm inlet or at the head of the field, depending on his views. The values of ET actual and the volume of irrigation water are heavily influenced by local climate. Gross value of production is the yield multiplied by the price of output, while the net value includes costs. This is useful when an irrigation system has multiple crops, especially grain and non-grain, like maize, potatoes and fruits. Increases in economic water productivity may indicate a shift towards higher valued crops or an increase in yields (Alterra-ILRI, 2005).

### C. Conveyance efficiency

Conveyance efficiency is defined as the ratio of the amount of water delivered at the turn outs of the main irrigation conveyance network to the total amount of water diverted into the irrigation system. It is one of several closely related and commonly used output measures that focus on the physical efficiency of water conveyance by the irrigation system (Değirmenci et al., 2003). The earliest irrigation efficiency concept for evaluating water losses was water conveyance efficiency (Hansen et al., 1980). Most irrigation water then came from diversions from streams or reservoirs. Losses which occurred while conveying water were often excessive. The FAO (2002), in Egypt concluded that water losses from canals are estimated at 25-50% of total water loss. In most sewer systems, most of the total production loss is steady-state seepage due to their continuous use. FAO (2002), the penetration of channels varies with the type of channel lining; hydraulic conductivity, the hydraulic gradient between the canal and the surrounding area, resistance layer at the channel edge, water depth, flow velocity and sediment load.

## 2.7.2. Scheme performance assessment

The selection of performance indicators depends on the purpose for which the assessment is being conducted (Small &Svendsen, 1990). The purpose of this study is will to evaluate and assess the given irrigation schemes to determine whether the intended objectives are met and identify the causes of underperformance of such irrigation schemes . Since the ultimate goal of irrigation systems is to provide appropriate water to the crops, factors that reduce the water supply are included.

Hence, our performance assessment of the irrigation schemes will conduct using the selected internal performance indicators of water delivery structures, water service, maintenance, and environment categories (Bos et al., 2005). We incorporated several factors to investigate the different causes of underperformance and identify possible solutions at the unit. Under scheme performance assessment will using the following scheme performance indicators as follow. (Abera et al, 2019)

- **Canal conveyance efficiency (CE).**The conveyance efficiency is the efficiency of canal and conduit networks from the reservoir, river diversion, or pumping station to the off takes of the distributaries system. Conveyance efficiency of the scheme is computed by taking discharges measurement at different points of canals. Canal conveyance efficiency (CE) will measured for randomly selected defined canal segments (50 m -100 m) in the tertiary canals to determine the conveyance loss using the inflow–outflow method. Discharge for unlined canals will measured using trapezoidal notches and discharge for concrete-lined canals by the float method. (Abera et al, 2019)
- **Cropped Area Ratio.** Is measured as the ratio of existing area under irrigation in given hector to the planned irrigated area .Sustainability of irrigable land (cropped area ratio) indicates the ratio of the currently irrigated area to the initial planned area: 2019)**.** Water-level ratio indicates the sustainability of the design water level and will calculate by dividing the water actually delivered to the command area by the design water level. The design flow of water for a given Block was obtained from the design document. Since the design flow was measured during the driest months of the year (February and March), actual water flow to the command area will measured by the float method during seasons, and taken the average values of the units (Abera et al, 2019).
- **Infrastructural Effectiveness (EI)**. The existing condition of infrastructural effectiveness of the canal at the branch canals are inspected in its operating length alone. Effectiveness of infrastructure (also called structural performance) is used to quantify maintenance performance to analyze whether the maintenance system is operating as designed. It is obtained by dividing the number of functioning infrastructures by the total number of infrastructures. The total number of infrastructures will counted and cross-checked from the design report ( Abera et al 2019).

### 2.7. 3.Overall scheme efficiency

Irrigation efficiency is assessed at the level of the plot or the level of the farm in order to determine the losses that occur in the irrigation system from the point of abstraction, through the transport system to the use of water in the field, to determine irrigation efficiency in general. As the Ministry of Land and Fisheries (2002) reported for small irrigation schemes in Tanzania, the typical values were 28 and 34 % proposed to run poorly, and the channels worked well, respectively. In addition to design and other technical factors, farm efficiency is largely regulated by operating the main supply system to meet actual field supply requirements and the skill of system operators (FAO, 1977). Irrigation efficiency is commonly used to assess the effectiveness of the irrigation system in delivering water for beneficial uses.

The overall irrigation efficiency (EO) represents the efficiency of the entire system to deliver water from a water source to a crop. The most common way to express the efficiency of irrigation systems is to subdivide it into conveyance and application efficiencies. Once the conveyance and field application efficiency have been determined, the scheme irrigation efficiency (ES) can be determined (FAO, 1989). According to FAO, (1989) the irrigation efficiency of the plan by 50-60% good; 40% reasonable, while the irrigation efficiency of the plan by 20-30% is considered poor. It should be borne in mind that the above values are only indicative values. The overall conveying efficiency of the lined, unlined section of the main channel and the field channel was observed to be 75, 52 and 34 %, respectively (Jia & Zheng, 2014).

## 2.8. Organizational indicators

### 2.8.1. The roles of water users associations

Attention is nowadays being focused on how to achieve this commitment, and to what extent WUAs can be assisted to form and to manage their own affairs (FAO, 1996). 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). Under the centralized governmental management, operation and maintenance activities were also usually inadequately performed (MoWR, 2002).

Since 1991 farmers or communities are forming their own organizational set ups (WUAs) for own and autonomous management of irrigation schemes with support from government and NGOs (FAO, 1998; (MoWR, 2002). However, most of the time WUA"s bylaws and administrative issues were not legally entitled and couldn't enforced in end, unless the communities ruled by own cultural rules. Finally the organizational structure and the level of management were indicated in map. Water use fee amounts for members and non members; way of estimation and collection; final utilization status were clarified. Beneficiary's degree of participations in operation and maintenance activities and number of rounds for canal cleaning in the production year also assessed. Functionality of bylaws and internal rules and regulations and legal enforcement status was identified. Water allocation at each organizational level, way of water allocation and gaps were clarified. Types of conflicts, causes of conflicts and conflict management experiences were assessed at each irrigation schemes

### 2.8.2. Institutional Factors

Improvement in irrigation performance depends on good government, or governance. This may be an obvious assertion, but what exactly does the term mean for irrigation. There are four main elements of governance which can be considered at the national or the local level: the legitimacy of government; its accountability, its competence; and its respect for human rights and the rule of law. According to World report on Governments and development in Washington, DC (1992), Legitimacy refers to the way in which a population gives consent to be governed, how they are consulted and whether the consent can be withdrawn. Accountability of politicians and officials is tested by how they explain their role and decisions, provide information and can be held responsible for their behavior. A government demonstrates competence in formulating policies and translating them into action in a timely and effective way. Governments who respect human rights establish a framework of known laws, applicable to all, without bias or corruption, with limits on and protection against the exercise of arbitrary power. He further noted that lack of support services like access roads, market outlets, electricity, have contributed to declining pace of projects .Small holder irrigation development that entails devising of a technical, social and economic productive systems that guarantees farmers goals of increased level of income, increased level of food security, employment and general improvement of their standard of living through effective management systems is vital. (Rukunga et al (2006).

### 2.8.3. Irrigation Institutional Arrangements

Irrigation institution is an entity of organization that is public, cooperative or private, engaged in irrigation investment and management (in which case it is a hard institution), or policies, laws, bylaws, rules and regulations, procedures, established customs guiding water use, investments, or water allocation mechanisms (a soft institution). Institutional Arrangements: are taken to cover the interrelated set of organizational entities, rules, incentives and cultural practices that affect or influence irrigation development and practice (MoWI, 2009)

Water laws provide the framework for water governance systems and are the pillars for achieving better governance system (Barreira, 2006). Water law refers to many issues including the legal status of water, water rights, conflict resolution mechanisms, and possible contradictions between laws, legal pluralism, administrative regulations, and implementation mechanisms (Saleth and Dinar, 1999.

Water administration involves organizations at policy level for resources management and organizations at implementation level for delivery management. Thus formal organizations, organizational procedures, pricing, finance and accountability mechanisms are the preoccupation of water administration. Institutional arrangements which provide positive incentives to use water more effectively are likely to be in the successful uptake and implementation of best water management practices which this will lead to higher productivity, increased and sustained profits, and a healthy environment (Lecler, 2004)

### 2.8.4. Irrigator's organizations

Irrigators Organizations (IOs) are the lowest appropriate level of management of irrigation schemes. The main functions of these organizations include management, distribution and conservation of water for irrigating their schemes; acquisition of the Water Use Permit from the respective Basin Water Offices; resolution of conflicts among members of the organizations related to the joint use of a water resource and collection of water charges for operation and maintenance and payment of water user fees to the Basin Water Offices. The Irrigators Organizations have other responsibilities which include planning of interventions on their schemes; the implementation of agreed and supported interventions, management and control of resource allocations for implementation of their planned investments and procurement of essential services for irrigation development (FAO, 2005; MoWI, 2009). The main challenges that require to be addressed in IOs are poor linkages with relevant institutions, lack of qualified irrigation professional staff, skills gaps, inadequate financing, inadequate equipment and facilities to undertake irrigation development (MAFS, 2004).

### 2.8.5. Social and Institutional Factors on Irrigation Schemes

Ethiopia has a political and legal framework that supports IWRM, but its implementation is poor; institutional roles are not well articulated, nor are coordination mechanisms for water resource management (especially at the sub national level) (Beatrice et al., 2015). There is a poor system management regarding the inadequacy and late maintenance of channels. Lack of effective coordination, inefficient control system, very weak links with relevant stakeholders; and lack of regular training is the specialty of many WUAs. Existing operational and maintenance issues and weaknesses in the capacity of WUAs are challenging (MoWR, 2001).

According to socio-economic institutional constraints ( MoWR, 2001) reported listed the following major problems.

- ✓ All levels; there is a low institutional capacity that is important for promoting LSI development, design, implementation, operation and maintenance, including irrigation advisory services.
- ✓ Water theft and water distribution are a common scenario in many schemes.
- ✓ Water user associations have weak coordination skills to solve problems related to the plan.
- ✓ Households with the highest current were receiving adequate water, while the lower-class beneficiaries did not receive it. As a result there was a kind of conflict and dissatisfaction.

# CHAPTER THREE

# 3. MATERIALS AND METHODS

## 3. 1.Description of the Study Area

Koga Irrigation scheme, where this study was conducted, is found in Mecha Woreda in the Amhara regional state (Fig. 3.1) which is located about 30 km South of Bahir Dar, the capital of the region. Koga Scheme extends from 11°20’N to 11°30’N (latitude) to 37°3’E to 37°9’E (longitude). The scheme has an average elevation of about 1980 m above mean sea level. Koga irrigation scheme is a large scale scheme designed initially to irrigate 7,000 ha command area and is divided in to 12 units. The scheme has about 20km long concrete-lined main canal, 52km concrete lined secondary canals, 156 km of unlined tertiary canals, 905 km of unlined quaternary canals and 11-night storages. Wheat, potato, barley, haricot bean and onion are the major irrigated crop in the scheme. For the purpose of measurement and detail sample collection of the study, one of the 12 irrigation units, called Inguit was selected as a study site.

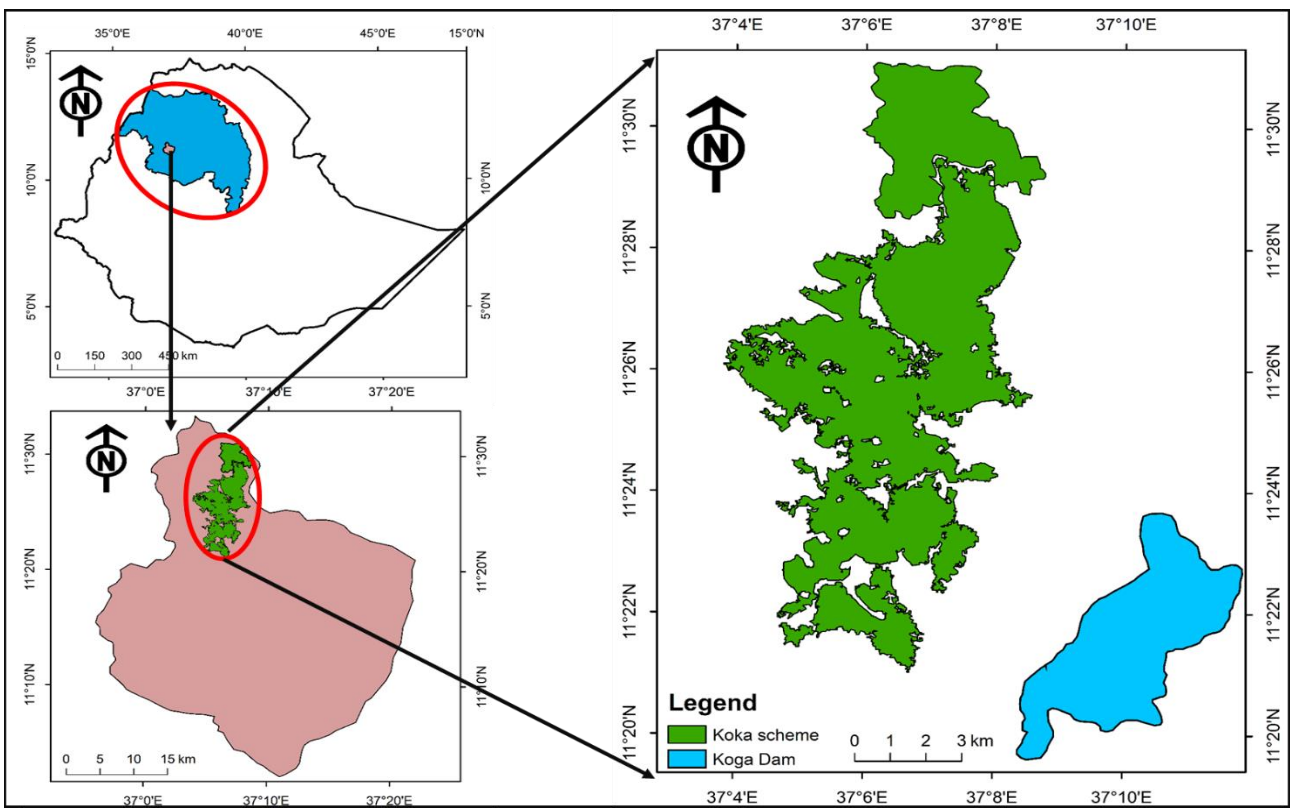



**Figure 3.1 Location map of the study area**

### 3.1.1. Location of the study site

Inguti unit was designed to irrigate total command areas of 393ha and is associated with 473 total households. The main purpose of the project is to irrigate 393 ha, and to improve the formerly used rain fed agriculture by allowing two crop seasons which will increase yield. A block is an area irrigated by a tertiary canal which takes off from a secondary canal. The command area of Inguti unit lies adjacent to right side of tertiary canals/two command areas only right users from tertiary canals and one is both left and right users

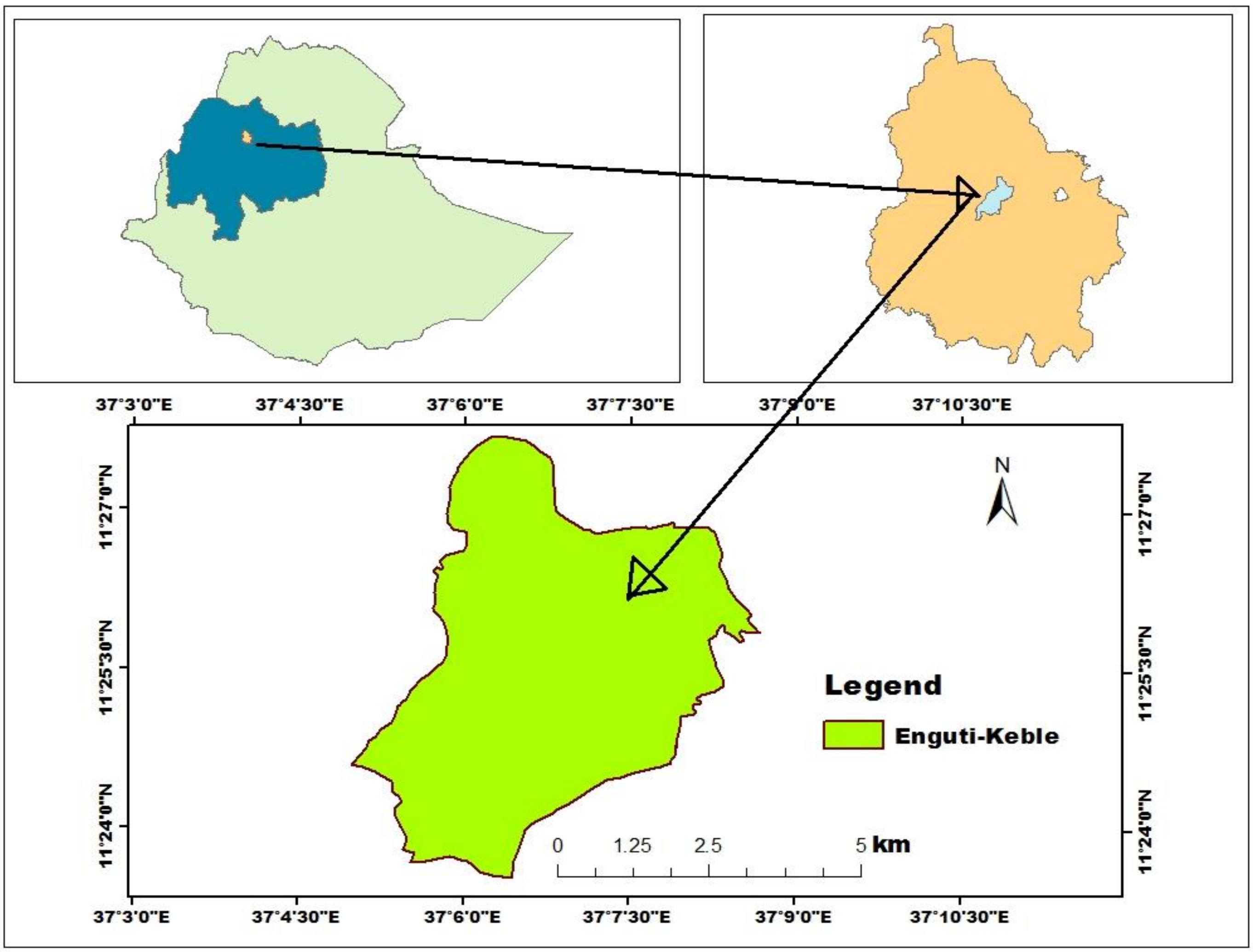



**Figure 3.2.Location experimental site**

### 3.1.2. Climate

The area is subject to the Intertropical Convergence Zone (ITCZ), northern trade winds and the southern monsoon (UNESCO, 2004). Thus it suffers from a dry period, called Bega, which begins in December and lasts until the end of May. From June to September there is a rainy season, called Kiremt. For rain fed farming, this would allow only one cropping season, referred to Meher in Ethiopia (Marx, 2011). Currently, the single most important climate parameter for crop and fodder production in Ethiopia is rainfall (UNESCO, 2004). The rainy period is associated with high flows in the rivers which in turn causes soil erosion which is considered as a serious problem. The annual precipitation ranges from 800 to 2200 mm, with a mean of 1,420 mm (Ministry of Water Resources, 1998 and Birhanu, et al., (2015). Studies on climate change for the area seldom shows uniform results concerning rainfall and dry spells (Marx and UNESCO, 2011 and 2004). Some predict an increase and some a decrease in future rainfall.

The average day time temperature of the study area is 24ºC. Mean maximum temperature varies from 30.1ºC in April to 24.3ºC in July and August; mean minimum temperature varies from 8.9ºC in January to 15.5ºC in May. The highest mean temperature is usually observed from March to May. The mean monthly relative humidity is 58.4%.The value of Relative humidity is highest during the humid rainy season from July to August, it becomes 75% and lowest during March 42.9%. Mean monthly sunshine hour varies from a low value of 4.4 h/d during the month of August (rainy season) to as high as 9.9 h/d during the month of December (Tesfaye and Fasile, 2011).

### 3.1.3. Soils

The soil in the study area are reddish brown soils in the irrigation area are relatively homogeneous and show similar physical and chemical characteristics (Ministry of Water Resources, 2006 and 2008). As much as 87% of the area is believed to consist of silt clay soils suitable for irrigation Macdonald (2006) see also figure 3.3. These are generally, well drained soils formed in the upland positions mainly in the downstream of the dam site and on both sides of the Koga River. These soils are intensively cultivated and possess good drainage and workability (Tesfaye and Fasile, 2011).

Overall, the soils are well suited for irrigation, with Foundations Red silty clay with (c(KN/m2) 5,Φ' 29°, density 16 KN/m3), Pale sol with (c'(KN/m2) 0, Φ'13°, density 16 KN/m3), Completely weathered basalt with (c'(KN/m2) 0, Φ' 30°, density 16 KN/m3) and with Fill Material Red silty clays with (c(KN/m2) 5, Φ' 30°, density 17.5( KN/m3) Macdonald (2006 ).

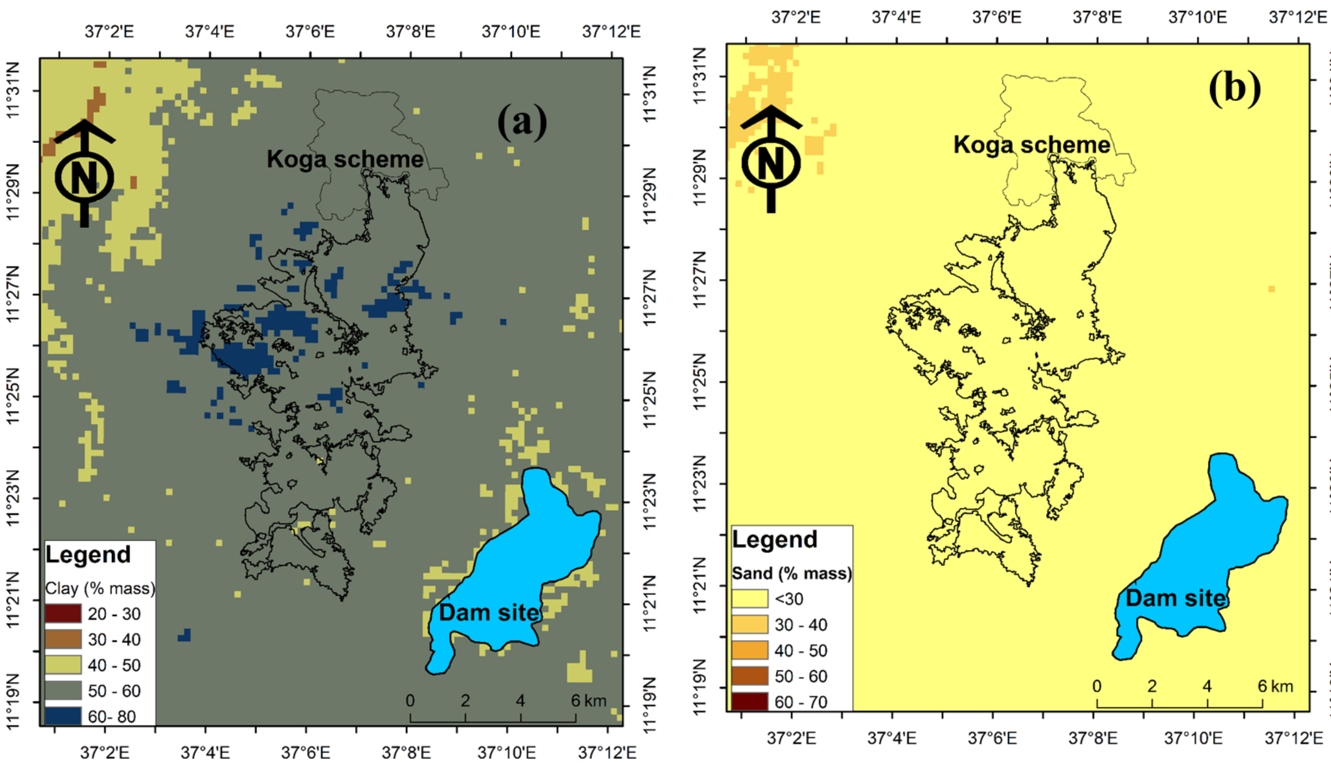



**Figure 3.3 The soil texture** (a) sand, (b) clay content by mass percentage of the Koga irrigation scheme and the main dam site (Source:Abebech (2018)).

### 3.1.4. Vegetation

The tree species that dominate the Koga watershed are Eucalyptus Camaldulensis, Gravelia Robusta, Coordinal Africana and Syniesse Mollie. The non-irrigated command area is dominated by Eucalyptus Camaldulensis for fuel wood, charcoal production and construction purposes that are planted perversely before irrigation scheme are designed. Based on field observations and discussions made with the local community and district experts, the natural vegetation in the lower watershed and command area is almost completely destroyed due to increased demand in the last decades for fuel wood, construction, timber and agricultural land. Currently, in the irrigation command area Eucalyptus Camaldulensis plats are not allowed to plant by legislations of the region.

### 3.1.5. Cropping practices

There are two types of agriculture in the study area: rain fed agriculture and irrigated agriculture. The major field crops grown are finger millet, wheat, maize, teff and barley. Horticultural crops include onion, potato, haricot bean, cabbage and pepper. The major crops that are produced in the rainy season include maize, teff, potato, Israel Avocado, paper, barley and wheat. The major crops grown using irrigation include; potato, onion, cabbage, pepper; haricot bean, wheat and maize (mostly green maize). Most crops grown with irrigation are produced for market / marketable commodity/.

### 3.1.6. The irrigation scheme

The scheme consists of different infrastructures responsible for water delivery and system operations. Koga irrigation scheme was designed for a command area of 7000 ha. The scheme has a 20 km long concrete lined main canal. 52km lined secondary canals, 156km unlined tertiary canals, 905 km unlined quaternary canals and 11 night storages from the 12blocks. The night storage reservoirs store water during a 12hr night time when the smaller canals discharge is low. They are surrounded by a geo-membrane lining which itself is protected by a layer of soil (Ministry of Water Resources, 2004). The main canal starts at the dam outlet and it crosses incised drainage channels and tributaries of the Koga and abay rivers (Ministry of Water Resources, 2004).

Inguti irrigation scheme is one of the twelve irrigation blocks of Koga irrigation scheme and it is located at11.9km from main canals and about 0.8 km from secondary canals .Inguti scheme has one night storage with a capacity of 18144$m^3$. The scheme consists of a number of irrigation infrastructures such as control gates/shutters/, Cross regulator, division boxes, culverts, sediment traps and drop structures. The most common irrigation infrastructures are briefly described in the figures 3.4 bellow.


**Figure 3.4. Irrigation infrastructures in the unites** (**A**) culvert, **(B**) drop structures, (**D)** control gate/shutters/, (**E**) Cross regulator) (**F**) night storage. (Author photos).

There is one secondary canal with a total length of 0.8 km that delivers water within individual command areas. They are designed for a 12 hr irrigation supply, but are also used to distribute water from the night storage reservoirs. They have the same lining system as the main canals and are in most cases in contact with natural drainage features or grazing land (Ministry of Water Resources, 2006).

There are three tertiary canals in the unit which have a total length of 3.37 km and they deliver water to unlined quaternary canals. All of quaternary canals in the field were completely unlined. One of the three tertiary canals is directly delivered water from secondary canals and others use from night storages as a source of water to deliver for quaternary canals. Just like the secondary canals they are under a 12 hr supply, but unlined “cut and fill” canals. In the study unit there are 26 quaternary canals which deliver water from tertiary canals to the fields.. The areas served by quaternary canals are generally 8–16 ha. Field canals are sometimes used to serve areas smaller than 2 ha. Some of the canals in the study irrigation unite are described in bellow figures 3.5.

Figure, 3.5: Tertiary earthen canals(TEC), Tertiary lined canals(TLC) secondary canals (SC)

**Figure, 3.5: irrigation canals in thee unite**

### 3.1.7. Farming system in the unit

The command area of Inguti irrigation Block is divided in to three different sub-units which are based on their areal extent and location of tertiary canals which suit to deliver waters for fields. It is supplied by the field channel for 12 hr per day from tertiary canals. When there is peak irrigation water demand, the fields are irrigated every 8 -12 days and are provided with 30 liters of water per second through field channels. The command area of Inguti unit lies adjacent to right side of tertiary canals(two command areas) only right users from tertiary canals and one is both left and right users. It is irrigated by tertiary canals which take off from the secondary canal However, Inguti unit have a total command areas of 393 ha to irrigate that included one block of Koga irrigation schemes with 473 beneficiary households.

Figure 3.6: Photo of irrigation command areas

**Figure, 3.6 irrigation command area**

## 3.2. Materials used for data collections

Augers were used to collect disturbed soil samples at the required depth whereas core samples were used to collect undisturbed soil samples. Sensitive weight balance was used to measure weight of soil samples and crop yield samples. Drying oven was used to dry soil for soil moisture content determination. Tape meter was used to determine the length of field and canal sections where the measurement was done. In addition, stopwatch and floating materials were used to determine flow rate using float method in both in earthen and lined canals. RBC flumes were used to measure filed discharge at earthen sections of field channels at the field inlet of the selected farm plot. Standard gagged type flumes were used to directly read the measurements of applied water depth in mm and field channel flow rates in L/s. Finally, carefully data recording was done using note books.

## 3.3 Methods of data collection

The required data for the study was collected from both primary and secondary data sources through literature reviews, communications and interviews with organizations or key stakeholders and physical measurements at field observations. Most of primary data were collected through field observations and experimentation and secondary data were also collected from key representatives such as the scheme operator, experts and concerned bodies of the unit. Relevant information regarding infrastructural performance and managerial issues that affects scheme performances and farm water managements were gathered.

### 3.3.1. Primary Data

The data collection was carried out in collaboration with agronomists, irrigation engineers, gate operators and other key organizations of the irrigation schemes. Primary data was collected through formal and informal communications and observations at key points of organizations and fields for assessing and evaluating the functionality of irrigation infrastructures specifically conveyance systems including canals, division box, controlled gates /shutters, drop structures ,silt traps and culverts and determine the performance of farm water managements (FWM) in relation with field water application efficiency ,FC,PWP and irrigation canal efficiencies they were applied to the farms.

The canal flow rate data collection was carried out from different points of the canal section is branching at the unit in a respective length of the selected canals both in lined and earthen canals by using float methods. Also field canals flow rate was measured by using RBC flumes which have a calibrated cylindrical staff gages depth in mm and flow rate in l/s and were taken average values of measurements. The flume was adjusted by water levels during installations to avoid external velocity from inlet and outlet side of the flumes to get accurate value of flow rates that applied to the farms.FAO CROPWAT 8.0 computer model was used to determine the crop water requirements (CWR), and monthly ET of the irrigated crops at field levels during irrigation season **(**January to April**).**

Field surveys, house hold surveys, key informant interviews with respective stakeholders, focus group discussions and officials from relevant government institutions have been deeply practiced for wellbeing of information gathering and analysis at the fields. The questionnaire was used to evaluate the degree and type of infrastructural performances and to evaluate the institutional support/issues for design, construction, operation and maintenance phases that improve the efficiency of irrigations schemes. Also various discussions with water users, elders and leaders, water committees, field operators/experts on the schemes are conducted using informal tools and semi structured interviews at unit of the scheme.

To understand and evaluate the realities of the existing infrastructural and managerial performance of the scheme repeated field visit was also conducted in which frequent observations and measurements were done. Data such as the situation of the existing condition of irrigation infrastructures, efficiency of field irrigation application, the feelings and attitudes of beneficiary farmers towards the scheme, sedimentation of canals, cracking of lined canals, water loss through the canal and other physically observed problems was collected.

The study was conducted during the dry season when the water is diverted in to the conveyance system and the crops are cultivated under irrigation. Measurements of discharge at tertiary levels of canal were conducted both in lined and earthen section of canal through float method in the trapezoidal lined canals and rectangular earthen canals sections and average discharge was used. And the total volume of water diverted by the irrigation scheme was estimated. During the study period, regular and repeated field visits, measurements and observations was made to assess, evaluate and investigate the performances of infrastructures to deliver water through the canals and related to farm water managements at the study sites of irrigation scheme in Inguti unite.

### 3.3.1. 1.Soil sampling and testing

Disturbed and undisturbed soil samples were collected at a depth of 30cm depending on the root depth of the irrigable crop in each area of representative irrigation sites and at the experimental site. The soil samples were collected after the rain stops and before the first irrigation starts. The collected soil samples were characterized in terms of physical characteristics of soil such as soil moisture content before and after 24 irrigations and bulk density at the soil laboratory of Bahir dar polytechnic water treatment laboratory and soil texture, FC and PWP at the soil laboratory of Amhara design and supervision enterprise soil laboratory.

**A. Measurements of soil moisture content**

Soil samples were collected to determine soil moisture content of irrigation fields with an interval of 30 cm of soil depth up to 60 cm depth taken from two locations per plots randomly selected just before irrigation and about 24 hours after irrigation events. Soil samples were taken to the laboratory three times at the growth stages of the potato (initial stage, developmental stage and late stage) per plot (36 soil samples were collected)**.**Potato is selected because it is appropriate for the study meaning proper furrow and ridge, entrance and end line and most of the farmers used to grow it and suitable for market access and their own food in the unite. The three field plots was selected based on the availability of water reaching from the conveyance system or distance from the water source to the command area. Initial moisture content of the soil before irrigation and moisture content after irrigation was determined using gravimetric method (weight basis). The moisture content in volumetric basis was determined by multiplying the gravimetric water content (weight basis) by the soil bulk density. The soil samples were placed in air tight containers of known weight and then weighed. The sample is then placed in an oven for 24 hours at 105°C with the container cover removed. After drying, the soil and container was again weighed and the weight of water determined as the pre and post readings. The gravimetric soil water content ($\mathrm{W\theta}$) was calculated as equation (3.1).

$$\mathrm{W\theta} = \frac{\mathrm{Ww - Wd}}{\mathrm{Wd}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Where: $\mathrm{W\theta}$ is gravimetric soil water content in weight basis, Ww is wet of the weight soil (gm), Wd is dry weight the soil (gm).The volumetric moisture content was calculated using equation (3.2)

$$\mathrm{\theta V} = \mathrm{W\theta} * \mathrm{Bd} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1.1$$

Where: θv = volumetric water content on a dry weight basis (%), $W\theta$ is gravimetric soil moisture content on a dry weight basis (%), $Bd$ is bulk density of soil (g /cm3).

**B. Soil texture, bulk density, field capacity and wilting point**

To determine soil texture, two disturbed soil samples were taken at 30 cm and 60 cm depths from each selected field and mixed to homogenize for the top 60 cm soil to average soil texture values for potato root zone. The texture was determined using hydrometer analysis and the soil textural class is determined by USDA soil textural triangle method (Bouyoucos, 1951).

Bulk density was determined using 18 undisturbed soil samples collected from three pits using a 5cm diameter and 5cm height cylindrical core sampler at interval of 30 cm soil depth in each plots. The samples were placed in an oven and dried at 105°C for 24 hours. After drying, the soil and container were again weighed. The dry weight of the soil was divided by the sample volume to determine the dry bulk density**.** Field capacity and Permanent wilting point of the three selected fields were determined in the laboratory using a pressure plate apparatus by applying a suction of 1/3 bar and 15 bar to a saturated soil samples respectively.

### C. Soil water availability

Soil water availability refers to the capacity of a soil to retain water available to the plants. After heavy rainfall or irrigation, the soil was drained for 24 hr to let to drain the water that contained in macro pores which in most cases are called field capacity. Field capacity is the amount of water that a well-drained soil should hold against gravitational forces, or the amount of water remaining when downward drainage has markedly decreased. Total available water (TAW) is the amount of water that a crop can extract from its root zone, and its magnitude depends on the type of soil and the rooting depth. Total available water (TAW) in volumetric base was computed from the moisture content in volume percent at field capacity and permanent wilting point and the TAW in percent also computed by subtracting from field capacity to welting point (Allen et al., 1998b)

$$\mathbf{TAW = 1000 \sum_{i}^{n} (\emptyset Fci - \emptyset Pwpi)\, Zri} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{3.1.2}$$

Where TAW= is total available soil moisture (mm); θFC$i$ =is volumetric moisture content at field capacity in the layer of the soil (m3/m3); θpwpi =is volumetric moisture content at permanent wilting point in the soil layer (m3/m3); n =is number of soil layers in the root zone and Zri= is soil depth in (mm).

### 3.3.1. 2.Measuring of delivered irrigation water at the canal

Canal Flow rate measurement is a relevant data for irrigation scheme performance evaluation activities including computation of conveyance efficiency and losses. Frequent flow measurements have been taken starting from intake to referenced point of secondary and tertiary canal using float method. Float method is used in measuring the flow in the canals to compute discharges were diverting to a fields.

To calculate the total amount of water diverted to the irrigation canal within a season, the flow velocity measurement is taken at three locations in the secondary and five locations in tertiary canals (head, middle and tail) of the canal per month and the average velocity were used within respective canal length where the canal is branched. The flow velocity was measure by the float method and it is multiplied by the areas of flow cross sections to change in to discharge. The water height/depth and width was measure by tap meters at two pointes and average value were used to estimate cross sectional area of the canals. After determining the flow velocity, the discharge was calculated using the following equations (Walker & Skogerboe, 1987).

$$Q = A * V \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where Q=total amount of water applied to field ($m^3/s$),

A = cross sectional area of the Trapezoidal lined canal ($m^2$) and

V= velocity of water (m/s)

### 3.3.1. 4.Velocity measurement

When measuring velocities, must specify the number of points per column and the number of columns for each cross section of the canals. For this purpose, the amount of work and time required for accuracy should be measured (Euro consult, 1989). From secondary canals taken three measuring points with three inflows and out flow measuring points.From each three tertiary canal at the units have 3 measuring points for lined canal and 2 measuring point for earthen canals were taken at each tertiary canals that have 5 inflow points and 5 outflow points in each canal. Inflow and out flow measuring point were considered for the accuracy of measurements at the different section of canals (head, Middle and tail).

Inguti irrigation block has three tertiary canals from thus one is diverted directly from secondary canals and others (two) were divert waters from night storages to quaternary canals which constructed in lined masonry and earthen materials with a total length of 2.1km and 1.1km respectively. The surface velocity determined by the float method as the ratio of float length to float time (Equation 3.7) was then converted to average velocity using coefficients. Average velocity of the flow profile in the canals is required as the velocity in the canals vary from top to bottom as a result of friction. Velocity is high at the surface of the water and decreases to the bed of the canal due to friction and corrected by the variation of velocity by multiplying average coefficient values (0.85) were used for lined and unlined canals (Tiggabu, 2017 and Harrelson, 1994).The canal cross sectional structure is trapezoidal shape. The velocity was measured by float methods in respective length of the canals at given tame taken by equation (3.7) and then multiplying by flow coefficient. The amount of discharge was determined as the product of the average velocity (V) and the cross section area (A) as shown above equation (3.6).

$$\mathrm{Vs} = \frac{\mathrm{LC}}{\mathrm{Tav}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots.3.2.1$$

Where, Vs=surface velocity, L is length of canals, T is average time taken of a float, and C is flow coefficient. Then, the average velocity was determined by multiplying the average surface velocity by the coefficients.

### 3.3.1. 5. Measurements of Canal Conveyance efficiency

The classical definition of canal conveyance efficiency is the ratio of the amounts of water delivered to the certain farm by the canal to amount of water diverted r from the source to the canal (Israelsen, 1932). The water conveyance efficiency depends on various factors such as canal length, soil type and material of the canal lining. A number of reaches are selected as a sample to determine the amount of water losses in the canals. Conveyance efficiency was used to evaluate the efficiency of the system conveying water. It is also used to measure the efficiency of channels conveying water from wells and ponds to fields.

Water conveyance loss consists mainly of operation losses, evaporation and seepage into the soil from the sloping surfaces and bed of the canal. Canal conveyance efficiency (CE) was estimated by dividing the discharges at outlet to discharges at the inlet where the discharge was measured by float method both in lined and earthen canals and the conveyance loss was also determined using inflow–outflow method after computations of discharges.(Abera.*etal*, 2019)

$$CE = \frac{Qo}{Qi} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2.2$$

Where CE= is the conveyance efficiency, Qi =is total water diverted into the canal, and Qo= is total water outflow from the canal (m3/s).

The loss of water measurements in the conveyance due to seepage and evaporation from irrigation canals constitutes a substantial part of the usable water. By the time the water reaches the field, more than half of the water supplied at the head of the canal is lost in seepage and evaporation but mostly evaporation is not consider for its loss within the ranges of sampling length was taken canals (Xie et al., 1993)..

The seepage loss in the irrigation canals accounts for the major portion of water conveyance loss due to the factors of canal types which is earthen or lining from the total water is lost due to evaporation. The lining of an irrigation canal has the advantages of reduction in seepage losses from canals reaching water table and raising it resulting in water logging and reduction in yield of seepage that compared from earthen canals, reduction in losses thereby making more water available for extension of irrigation to new areas and improvement of irrigation facilities in the areas already under irrigation. In the study area water loss was determine in the canal by using inflow -outflow methods after measuring of discharges at different section of both lined and earthen canals at the unite.

$$\mathbf{SL = Q_{in} - Q_{out}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . 3.3.3$$

Where, SL is seepage loss, Qin= inflow and Q-out = out flow in specified canal reach all unites in $m^3/s$.

### 3.3.1. 7. Measurement of amount Irrigation water applied to the field

Applied irrigation water to the field was measured using RBC flumes with standard calibrated staff gage readings. RBC flumes were installed at the entrance of irrigation water to the field for the selected farm test plot within keeping the level of flume. The RBC (Replogle-Bos-Clemmens) flume has a short trapezoidal section with a contraction inserted in the flume bottom which is a simple and reliable instrument for the measurement of the quantity of irrigation water that flows towards a field channels. Constructing an RBC flume, is not absolutely necessary simply follow the standard measures/readings directly from flume calibrated cylindrical staff gages which have applied water depth in mm and discharges at field Channel in l/s lies on flume stilling well.

The standard program contains flumes with various measuring ranges, varying from 0.1-8.7 l/sec to 2.0-145 l/sec (Bos and , Clemmens ,1984).The value of the water rise/head was read in the measuring instrument (measuring cylinder staff gages on the stilling well of flume in mm) at the end of the measuring channel and the flow rates (discharges) were also read at the ends of calibrated cylindrical staff gages lies on flume stilling well in l/s and the average values were taken. During installations the levels of flume was cheeked and/or adjusted by carpenter's level to avoid external flow velocity in order to obtain accurate measurements and readings from the flume (Replogle-Bos-Clemmens, 1984).Applied irrigation was measured in all crop growth stages and this data collection was done based on farmers opinion until they feel that enough water is applied to their field. When they completed irrigating their plots, the average depth of irrigation water passing through the flume and the respective time was recorded.

Figure 3. 7: Field water application depth and discharge measurement with RBC flume.

## 3.4. House hold survey and Sampling techniques

In the irrigation unite data about organizational arrangements, technical problems/gaps, awareness/attitude for water application, WUA, community level problems and experiences were collected through questionnaire, key informant interview and focus group discussions.

### 3.4.1. Sampling techniques

From the total population of Inguti Keble 493HHs live in the command area were the beneficiaries have been used as a sample frame/population/ for the determination of sample size which own irrigable land for head, middle and tail-end. Israel, (1992); Yamane, (1967) provide a simplified formula to calculate sample sizes.

$$\mathbf{N = \frac{n}{1 + n(e)2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . 3.3}$$

Where: N= Sample size, n= Population size/sample frame, e= Level of precisions. For this study the calculation has been carried out through using 95% confidence interval. (α=5%), 10% precision level and 50% degree of variability (P).

$$N = \frac{493}{1 + 493(0.1)2} = 83HHs$$

Stratified random sampling consists in dividing the population into groups, or strata and taking a sample random sample from each stratum, were done to improve the accuracy of estimate, to reduced cost to make it possible to compare strata (Stone et al., 2004). Key informant interview was conducted from gate operator ,chairman of WUA; vice chairman of WUA; three water user leaders (WUL) of the scheme with each field canal; and district agricultural and rural development office and irrigation expert. The house hold survey, at the time of interviewee period farmers were not voluntary to exist at development agent's office DA‟s) based on the request. Due to this the number of house hold must be reduced from the previous planned or calculated (83HHS)to 55HHs.From the total 55HHs, 30 respondents are male and 25 respondents are female that were interview in the command area. Group discussion was applied with WUA committee and three selected water user group leaders at head, middle and tail of the scheme.

### 3.3. 2.Secondary data

Secondary data included discharge data (release to the unit from the secondary canal system), design reports, operation and maintenance and progress necessary report, project documents, studies and other useful written materials. These data included design and layout of the scheme, design of conveyance, design discharge working sheet and water control structures, irrigated area, area irrigated per crop per season/year are collected. Secondary data were collected from key stakeholders related to our study such as Amhara Water, Irrigation and Energy development Bureau, National metrological station Bahir Dar Brach, Koga Dam and Koga irrigation project office and Wereda agricultural offices.

Long time average climatic data of mean monthly minimum and maximum temperature and rain fall, relative humidity, wind speed and sunshine hours were collected from Bahir dar meteorological station for our study site was used for calculating ETc. Additional secondary data of total command area, irrigable area and irrigated area of the Koga Large Irrigation Scheme were collected from Merawi Woreda and Zonal agricultural experts, DAs, reports, research publications and design documents and from respective stakeholders.

## 3.5. Data Analysis Techniques

The collected data were analyzed using excel (for calculations and graphs). Cropwat8.0 were used (to determine crop water requirement) and GIS (for geo referencing and mapping). Finally the selected performance indicators were computed for evaluations of its performances and farm water management.

### 3.5.1. Determination of crop water and irrigation water requirement

The amount of water needed for the irrigated crop fields was determining using CROPWAT version 8 computer programs. Crop water requirements (CWR), irrigation requirements (IR) and scheme water demand for varying crop patterns was estimated based on the soil, climate, and crop patterns. Data input to CROPWAT8.0 include; climate data for determining the reference crop Evapotranspiration (ETo), rain, crop, soil and crop pattern data. There are three calculation modules (crop water requirement, schedule and scheme) used for determinations. We used monthly average minimum and maximum temperature, sunshine hours, relative humidity and wind speed as an input to calculate mean monthly ETo in mm/day using Penman-Monteith equation.  The effective precipitation was calculated using precipitation input data for CWROPWAT8.0 and it uses USDA method.

The program estimates the crop evapotranspiration (ETc) based on equation of (3.8) bellow

$$ET_c = ET_o \times k_c \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..\dots\dots..3.4$$

Where; Kc= crop coefficients, varies with a crop growing stages. The value of Kc of each major crops were taken from FAO I & D 56 ( Allen et al., 1998) and 24 (Allen & Pruitt, 1991) papers.

To evaluate water delivery and utility of water supply indicator, the flow rate to feed the each block was converted in to discharge (Q, in $m^3/s$), which is the product of IR in l/s/ha per month and the command area (ha) served for irrigation practice. The irrigation requirement (IR) indicates the difference between the Evapotranspiration of the crop under ideal conditions (ETc) and the Effective Rainfall (Pe) contributions during the same time period Aksara and Pasin, (2015) and it is expressed in mm or m3. In order to compute the irrigation water requirement, CROPWAT 8.0 computes a daily water balance of the root zone. Computed as;

$$IWR = ETc - Pe \qquad 3.4.1$$

And to estimate the total crop water requirement at scheme level input data of actual irrigated area by crop type will included.

## 3.5.2. Technical scheme performance and farm water management evaluations

### 3.5.2.1. Farm water management evaluation

On-farm water management (OFWM) problems have been a threat to agriculture in many countries around the globe in the last few decades. However, these problems have now grown larger and there is increasing public demand for the development and management of land and water to be ecologically sustainable as well as economic. As there is a close interrelationship between land use and water resources, farmers need to be aware of this interrelationship and adjust their OFWM efforts in order to address the issues. In their management efforts they need to consider both the on-site and the off-site effects on water management activities (Wolff and Stein, 1999).Farm water management of the existing irrigation practice was evaluating using the following selected internal performance indicators for the study units called Inguti irrigation Block.

**A. Field irrigation application efficiency (AE; %)**

. Field application efficiency is the relation between the quantity of water furnished at the field and the quantity of water needed, and made available, for evapotranspiartion and field water losses by runoff or deep percolation. The evaluation of the field application efficiency requires the measurement of water deliveries to each field and measurements of soil water content before each irrigation application. Field irrigation application efficiency can be useful performance indicator overtime that reflects losses of water below the crop root zone; (Kijne, Barker, &Molden, 2003) and was determined by the ratio of depth of water add to the root zone to the depth of water apply to the field (Bos et al., 2005; Howell, 2003) as follows:

$$Ea = \frac{Dr}{Df} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5.1$$

Where' Dr is the depth of water added/stored to the root zone and Df, is the depth of water applied to the field, both in (mm).

The depth of water stored in the root zone (Dr) was calculated(Equ.3.8.3.1) by subtracting the average soil-water content just before an irrigation event from the soil-water content 24 h after the irrigation event (cm3) (moisture difference), multiplied by depth of root zone (mm) and bulk density in $gm/cm^3$ Isrealson et al. (1944) and Imark et al. (2011).

$$Ws = MC * Bd * Rz \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5.2$$

Where: Ws = Depth of water stored in root zone (mm), M.C = Average Moisture content of soil (%) Bd = Bulk density of soil (gm/cm3),Rz = Depth of root zone of crop (cm). The root zone depth (Rz) for crops under study was taken from the literature (FAO) depending on soil type depth to water table.

To determine the amount of water applied (Df) by irrigation to the field/plot, RBC flume was installed at the entrance of each test plot (See Figure 3.7). Frequent readings were taken when the farmers were irrigating the test plots. Irrigation continued until the farmers' thought that enough water had been applied to the field for the whole growing stage of the crop and carefully reading and recordings was done.

Application of irrigation water by farmers was also evaluated by comparing crop water demand and irrigation applied for Water demands of selected crops (Potatoes) were modeled using FAO Cowpat 8.0 using 10 year averages (2009-2019) climate data collected from the stations and crop characteristics were obtained from Allen et al. (1998).

**B. Storage efficiency (Es %)**

The amount of water needed in the root zone is the difference between moisture content corresponding to approximately the field capacity and the moisture content in the root zone before irrigation and the type of crop grown. The water needed in the root zone prior to irrigation (depth of required) is calculated by at 75% moisture depletion level for most vegetable crops using equation 3.8.4(Allen et al, 1998)

$$Wn = TAW * BD * RD * Df \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5.3$$

Where : Wn = the depth of water needed or required in the root zone prior to irrigation(mm),TAW Total available water in%, bulk density of soil, RD, total soil depth in mm and Df, depletion factor in%

The water storage efficiency evaluates how completely the water needed prior to irrigation has been stored in the root zone during irrigation. Using FC in volume basis, bulk density and volumetric soil moisture content of the soils before irrigation at different depth, water requirement of the root zone profile was computed. The depth of water retained in the root zone was calculated using equation (3.8.3.1). After determining the depth of water stored and required water depth in the root zone, the storage efficiency was calculated using equation (3.8.5) it is the ratio of quantity of water stored in the root zone during irrigation event to that required to the field (Garg, 1989).

$$Es = \frac{Ws}{Wn} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5.4$$

Where: Es , storage efficiency (%)Ws, stored water depth (mm)Wn , required water depth (mm)

### C. Deep Percolation Ratio

The loss of water through drainage beyond the root zone is reflected in the deep percolation ratio, DPR. High deep percolation losses aggravate water logging and salinity problems, and leach valuable crop nutrients from the root zone. Depending on the chemical nature of the groundwater basin, deep percolation can cause a major water quality problem of a regional nature. The runoff ratio is normally considered for this particular study as zero as the farmers are using furrows whose tail ends are closed, runoff ratio is neglected. Field loss of water through drainage beyond the root zone is reflected only in the deep percolation ratio that expresses the ratio between the percolated water beyond the root zone to the volume of water applied to the field without considering ground water situations. Also the evaporation from the soil is marginal and can be neglected because it is only a short period after irrigation. Deep percolation ratio (field water loss in relation to field water application) could be calculated indirectly from values of application efficiency and runoff ratio as given by Feyen and Dawit(1999)

$$DPR = Ea - RR \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5.5$$

Where

DPR=deep percolation ration (%) Ea= application efficiency and RR=runoff ration

### 3.5.2.2. Scheme performance assessment using Indictors

The technical evaluations were made for the following internal and physical indicators ; namely, conveyance efficiency, application efficiency, Water-level ratio, Cropped area ratios/ sustainability of irrigable area and Infrastructural Effectiveness for selection of indicators depends on the purpose of the assessment (Burt et al., 1997).Internal indicators enable comprehensive understanding of the processes that influence water delivery service and the overall performance of a system (Renault et al., 2007). Three efficiency indicators are considered to give the overall scheme efficiency; (conveyance efficiency, application efficiency, water storage efficiency).

The selection of performance indicators depends on the purpose for which the assessment is being conducted (Small &Svendsen, 1990). The purpose of this study was to evaluate and assess the given irrigation schemes to determine whether the intended objectives were met and identify the causes of underperformance of such irrigation schemes. Since the ultimate goal of irrigation systems is to provide appropriate water to the crops, factors that reduce the water supply were included. Hence, our performance assessment of the irrigation schemes was conducted using the selected internal performance indicators of water delivery structures, water service, maintenance, and environment categories (Bos et al., 2005). We incorporated several factors to investigate the different causes of underperformance and identify possible solutions at the unit. Under scheme performance assessment was using the following scheme performance indicators as follow (Abera et al, 2019).

**A. Canal conveyance efficiency (CE;%)**

The conveyance efficiency is the efficiency of canal and conduit networks from the reservoir, river diversion, or pumping station to the off takes of the distributaries system. Conveyance efficiency of the scheme is computed by taking discharges measurement at different points of canals were branched. Canal conveyance efficiency (CE) was measured for selected defined canal segments both secondary and tertiary canals. Conveyance losses from lined and earthen sections of canal irrigation network are determined under existing situation and the scenarios for different management strategy were developed to utilize saved water for in irrigation schemes. Canal conveyance efficiency (CE) was estimated by dividing the discharges at outlet to discharges at the inlet where the discharge was measured by float method both in lined and earthen canals and the conveyance loss was also determined using inflow–outflow method after computations of discharges.(Abera.eta, 2019)

$$\mathrm{CE} = \frac{\mathrm{Qo}}{\mathrm{Qi}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.3.6.1$$

Where CE is the conveyance efficiency, Qi is total water diverted into the canal, and Qo is total water outflow from the canal (m3/s).

Conveyance Loss = Qin − Qout …………………..…………………….………. 3.6.2

Where Ec = conveyance efficiency (%) L = conveyance loss; Qin = the inflow and Qout = out flow in specified canal reach and is effective conveyance ratio that represents the capability of a canal reach to carry water with loss. Conveyance efficiency (CE), for lined canal this is assumed at 0.9, and for unlined canal could be down to 0.7 (Halcrow & Powell, 1992).

**B. Water-level ratio (WLR)**

Water-level ratio indicates the sustainability of the design water level called water delivery performance and was calculating by dividing the volume of water actually delivered to the command area by the design water level (equation 3.9). The design flow of water for Inguti Block was obtained from the design document (MottMacDonald (MMD, 2004 and (Asers et al, 2016). Since the design flow was measured during the driest months of the year (February to May), actual water flow to the command area was measured by the float method during seasons, and taken the average value of the units.

$$\mathrm{WLR} = \frac{\mathrm{ADWC}}{\mathrm{DWL}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.3.6.3$$

Where, WLR is water level ratio, DWL is designed water level in the canal and ADWC is actually diverted water to command area.

**C. Cropped Area Ratio (CAR)**

Cropped area ratios also known as sustainability of irrigable area were used as an indicator (parameter) to measure the technical performance of the scheme. Sustainability is a complex issue, under scarce data; Bos et al. (1994) suggested that a ratio of current irrigated area to initial total irrigated area is a good indicator of irrigation scheme sustainability. In fact, 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. Sustainability of irrigated area is the ratio of currently irrigated area to initially irrigated area when designed (M.G. Bos 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

$$\mathrm{CAR} = \frac{\mathrm{CIA}}{\mathrm{PIA}} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 3.6.4$$

Where CAR is crop area ratio, CIA is current irrigated area in ha and PIA is planned irrigated area in ha.

**D. Infrastructural Effectiveness (EI)**

The study was also focused on the irrigation structural system components well performing to designed schemes. The existing condition of infrastructural effectiveness of the canal at the branch canals are inspected in its operating length alone. Effectiveness of infrastructure (also called structural performance) is used to quantify maintenance performance to analyze whether the maintenance system is operating as designed. It is obtained by dividing the number of functioning infrastructures by the total number of infrastructures. The total number of infrastructures was counted and cross-checked from the design report (MottMacDonald (MMD, 2004).

$$\mathrm{EI} = \frac{\mathrm{NFS}}{\mathrm{TNSI}} * 100 \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 3.6.5$$

Where, is effectiveness of infrastructures, NFS is number of functional structures and TNSI is total number of structures initially installed.

**E. Overall Scheme Efficiency (Et)**

The efficiency of an irrigation scheme is derived from two components. The conveyance efficiency (off-farm, Ec indices') was calculated (equ.3.9.2) according to water losses were occurring when water is delivered to farms (e.g., through seepage and evaporation from canals) and application efficiency (on-farm indices) was competed in (equ.3.8.3) The overall irrigation efficiency (Et) represents the efficiency of the entire physical system and operating decisions in delivering irrigation water from a water supply source to the target crop. It was calculated by multiplying both components efficiencies of water conveyance and water application efficiencies (Walker, 1989).

$$\mathbf{Et} = \frac{\mathbf{Ea*Ec}}{\mathbf{100}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. \ldots\ldots\ldots 3.7$$

Where: Et=overall irrigation efficiency Ec=conveyance efficiency (%) Ea= Average application efficiency.

## 3.6. General Framework of the methodology

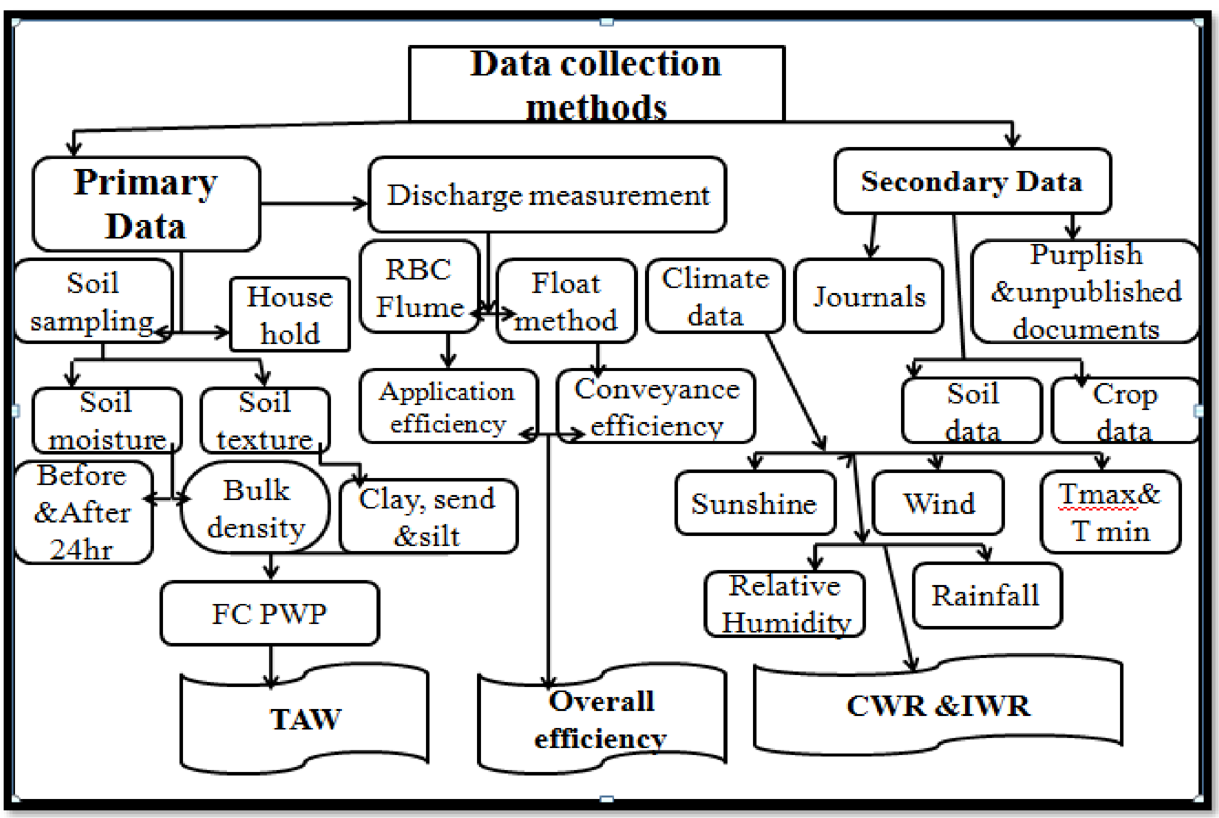



Figure 3. 8: Schematic diagram of methodology flow chart

# CHAPTER FOUR

# 4. RESULTS AND DISCUSSIONS

## 4.1. Analysis of Soil Physical Properties of the Study unites.

### 4.1.1. Soil texture

Based on laboratory analysis of particle size distribution, the textural class was found to exclusively heavy clay at all depths (Table 4.1), the test results of the plots showed that the composition of sand, silt and clay (average percentage) were 12.67%, 20.00% and 67.50%, respectively. According to USDA soil textural triangle textural classification, the soil is classified as heavy clay soil at the experimental unites.

### 4.1.2. Bulk density

The bulk density of soil of the experimental area showed that a variation with increasing the soil depth (Table 4.1). It varied between 1.15 to 1.25 g / cm3 and generally the top surface soil had lower bulk density than the subsurface. The top 0-30 cm has an average bulk density of 1.18 whereas; the subsurface 30-60 has an average bulk density of 1.25 g/cm3. The weighted average bulk density of the soil in the experimental site was found to be 1.21 g/cm3**.** According to obtained result for subsurface bulk density of soil showed a little higher than values for surface bulk density of soils. This might be attributed to relatively low organic matter content and compaction effect due to overlaying material at the depth of 30 – 60 cm. According to Mekonnen et al., (2014), recommended soil bulk density is below 1.4g/cm3 for clays and 1.6 g/cm3 for sands in order to get better plant growth. The result of the study area shows that the bulk density is lower than 1.4 g/cm3. As the bulk density values of the soils at irrigation schemes were low as per the bulk density rating of (Vanden Aker et al., 2003) and hence Jones et al., (2003) indicated that there was no compaction that could limit infiltration of water into and through the soil and root penetration of such soils.

**Table 4.1: Soil physical properties**

| Field | soil depth | PH (H2O) | Particle size distribution (%) | | | soil textural class | Bulk density (g/cm$^3$) | FC (%) | PWP ( %) | TAW (%) | TAW ( mm) | TAW (mm/m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Send | Silt | Clay | | | | | | | |
| **Head** | 0-30 | 4.76 | 9 | 15 | 76 | Heavy Clay | 1.15 | 26.88 | 16.79 | 10.09 | 34.81 | 116.04 |
| | 30-60 | 4.98 | 17 | 19 | 64 | Heavy Clay | 1.25 | 26.75 | 16.64 | 10.11 | 37.91 | 126.38 |
| **Middle** | 0-30 | 4.71 | 17 | 21 | 63 | Heavy Clay | 1.23 | 27.35 | 18.05 | 9.3 | 34.32 | 114.39 |
| | 30-60 | 4.84 | 9 | 25 | 66 | Heavy Clay | 1.24 | 27.23 | 17.91 | 9.32 | 34.67 | 115.57 |
| **Tile** | 0-30 | 4.72 | 13 | 25 | 62 | Heavy Clay | 1.15 | 25.14 | 17.29 | 7.85 | 27.08 | 90.28 |
| | 30-60 | 4.89 | 11 | 15 | 74 | Heavy Clay | 1.25 | 24.95 | 16.59 | 8.36 | 31.35 | 104.50 |
| **Average** | | **4.82** | **12.7** | **20** | **67.5** | **Heavy Clay** | **1.22** | **26.4** | **17.2** | **9.2** | **33.36** | **111.19** |

Source: Laboratory result (Appendix figure 1)

**Note**: FC, Field capacity, PWP, Permanent Wilting point And TAW, Total available water in millimeter and per meter. Head, upstream water user, Middle, middle stream water user and Till, downstream water user.

### 4.1.3. Field capacity, Permanent wilting point and Total available water

Field capacity is the amount of water remaining in the soil a few days after having been wetted and after free drainage has ceased and permanent wilting point is the water content of a soil when most plants growing in that soil wilt and fail to recover their growing upon rewetting where computed in the laboratory .Total available water amount of water available, stored, or released between field capacity and the permanent wilting point water contents were computed the difference between moisture content at field capacity and wilting points. Computed soil moisture characteristics values of field capacity (FC), permanent wilting point (PWP) and total available water content (TAW) are indicated in above (Table 4.1). The soil moisture content at field capacity (Table 4.1) varied from 24.95% to 27.35% by volume. The soil moisture at permanent wilting point varied from a minimum value of16.59% to the maximum value of 18.05% on volume basis. The value of total available water (TAW) varied from the lower value of 90.28 mm/m to the higher value of 126.38mm/m. The average calculated value of total available water of the irrigation scheme was 111.32mm/m within not in 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.

## 4.2. **Estimation of Reference Crop Evapo-transpiration (ETo)**

To determine the crop water requirement of potato in the whole growing season, the meteorological data collected in Bihar dare metrological station shown in (Appendix table 16) were used as input for the CROPWAT 8.0 computer software programs and the reference evapo transpiration of the study area was computed by entered dates of mentioned earlier and the result of Eto values were presented in (Appendix table 6).The maximum and minimum daily evapo transpiration (ETo) values of Inguti irrigation scheme were 3.95mm/day in April at the middle stage growing period and 3.02mm/day in January at initial stage of growing period . The estimated average daily ETo values of schemes were 3.46 mm/day.

## 4.3. Characterization of the scheme

Reports and majority of field survey indicts (Appendix table 15) that Ingutie irrigation scheme was officially developed in 2002 E.c where found in Koga large scale irrigation scheme as one blocks/unites of irrigation schemes which have one lined secondary canals with a total length of 0.779km to delivered water from reservoirs (night storage) with a total storage capacity of 18144 $m^3$ where located on the head of the scheme. Inguti irrigation scheme have three tertiary canals with a total length of 3.2km both lined and earthen canals that were supplied water from secondary canals to quaternary canals.

The planned irrigable area of the scheme (Appendix table 15) was 391 ha. However, the actual area developed for irrigation was 368ha; currently the actual irrigable area was reduced by 23ha compared with initially planned irrigable areas. The numbers of beneficiary households that own irrigable land were 493 out of which 150 were members of the WUA and the remaining 343 were non-members. During this survey, the majority of the scheme infrastructures (drop structures, division box, gate shutters and other structures) were functional. However, there are an number problems were faced in the scheme illegal water abstraction , canal breaching ,water theft and damaged of earthen canals by donkey carts. Majority of Farmers practice furrow irrigation with a length of 8m to 54 m. There is no restriction for the type of crop one grows by farmers, but the majority of crops grown by farmers were wheet, potatoes and onion (40%, 35, & 25) respectively.

## 4.4. Technical scheme performance and Farm water management Evaluations

The parameters where assessed for infrastructural performances and Farm water management Evaluations of Inguti small scale irrigation Scheme were used Infrastructural effectiveness, conveyance efficiency, field water application efficiency, storage efficiency, water level ratio, cropped area ratio and finally overall scheme efficiency were computed and presented in bellow performance indicators. Institutional and support service performance evaluation of the scheme was also conducted to incorporate local knowledge and perspective on the irrigation system.

### 4.4.1. Scheme performance evaluation

The selection of performance indicators depends on the purpose for which the assessment is being conducted that were used to evaluate the performance of irrigation schemes with determine whether the intended objectives are met and identify the causes of underperformance of the schemes that was faced . Hence, our performance assessment of the Inguti irrigation schemes was conducted using the selected internal performance indicators stated below.

#### 4.4.1.1. Conveyance efficiency (CE*)*

The water conveyance efficiency was estimated using Equation 3.8 for each measurement at each selected location along the secondary canal and tertiary canal.

### A. Secondary canal Conveyance Efficiency

Conveyance efficiency of secondary canal, which indicates the amount of water lost during transportation of water from the reservoir or source to the tertiary canal that is used to evaluate the efficiency of the system conveying water. The water conveyance efficiency was determined using equation (3.8) for each measurement at each selected location along the secondary canals and the estimated average value of inflow, outflow, water conveyance efficiency and water conveyance losses for different sections of the secondary canal were presented in (Table 4.2). The water conveyance efficiency for secondary canal was varied from 85.5% to 90.1% at different measuring pointes and the average value secondary canal conveyance efficiency was equal to 86.6%.

**Table 4.2,: Secondary canal conveyance loss and conveyance efficiency in the unit.**

| | | **Average Q in m3/s** | | | **Conveyance loss** | | | | **Conveyance Efficiency ( %)** |
|---|---|---|---|---|---|---|---|---|---|
| **Canal type** | **Canal Length (m)** | **Q in ($m^3/s$) Inflow** | **Q in ($m^3/s$) Outflow** | **Q ($m^3/s$)** | **Q ($m^3/s$)** | **Q (l/s)** | **Loss (%)** | **Loss (L/s/m)** | |
| LSC | 325 | 0.415 | 0.355 | 0.385 | 0.06 | 60 | 14.5 | 0.18 | 85.5 |
| USC | - | - | - | - | - | - | - | - | - |
| LSC | 251 | 0.334 | 0.284 | 0.309 | 0.05 | 50 | 15.0 | 0.19 | 85.0 |
| USC | - | - | - | - | - | - | - | - | - |
| LSC | 165 | 0.281 | 0.255 | 0.269 | 0.28 | 28 | 10 | 0.16 | 90.1 |
| USC | - | - | - | - | - | - | - | - | - |
| **Average** | | | | | | **46** | | **0.18** | **86.6** |

**N. B: -** LSC, Lined Secondary canal and USC, Unlined Secondary canal (none)

Water conveyance loss consists mainly of operation losses, evaporation and seepage into the soil from the sloping surfaces and bed of the canal. The seepage loss in the irrigation canals accounts for the major portion of water conveyance loss (15%) of water lost due to seepages were presented in (table 4.2) computed by equation 3.8.1 .The water conveyance losses L/S/M of secondary canal varied from 0.16/1s/m to 0.19l/s/m with average value equal to 0.18l/s/m. The lining of an irrigation canal has the advantages of reduction in seepage losses from canals were properly managed and maintained the canals to compare with unlined canals which highly affects by seepage loss. However, the maximum water loss observed was 0.19 l/s/m on the 251m length canal section of secondary canal this compared to other sections of measuring pointes of canals (Table 4. 2). Reason being this section was highly cracked and malfunctioning of control gates which caused high seepage and leakage losses in the canals that affects the canal efficiency.

**B. Tertiary canal Conveyance Efficiency**

Determination of Conveyance efficiency in the tertiary canal was vital to evaluate the amount of water lost during transportation of water from the source (secondary canals) to the field canals. Conveyance efficiency in the tertiary canal was estimated at different section of the canal length and the value was averaged in each blocks of the scheme were computed both lined and earthen canal efficiency along its own length of the canals. Inguti small scale irrigation scheme about 2.1km length of the tertiary canal was lined and the remaining 1.27km is unlined which a total length of tertiary canal at the unit both lined an unlined was 3.37km.

The estimated average value of inflow, outflow, water conveyance efficiency and water conveyance losses for different sections of the tertiary canal in each blocks were presented in (Table 4. 3). The average water conveyance efficiency for tertiary canal both lined and unlined canal varied from 89.33% and 64.2% and the average value of both lined and unlined canal was 77.76%. The maximum and minimum water conveyance loss observed in tertiary canals was varied from 0.23 l/s/m on TC (01) to 0.09l/s/m on Tc(05) were compared to other sections of measuring pointes of the canals (Table 4. 3).The reason ,being in this section of canal was observed maximum water lost (Tc,01) due to the factors of canal type(earthen),poor maintenances( cleaning) and blocking of canals with crop residues/or other debris of the scheme (Figure 4.2) which results side eroding of canal wall and re-growth of grass in the canals to reduces conveyance efficiency. The value of conveyance efficiency was different for each sections of canal were measured and estimated along a respective length of canals. This indicated that the conveyance efficiency of lined canal is bellow the recommended 95%for lined canals while 80 % unlined canals for clay soil (FAO, 1989)

Table 4.3: Tertiary canal conveyance loss and conveyance efficiency in the unit.

| | **Q in m3/s** | | | | | **Conveyance loss** | | | | **CE (%)** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Canal code** | **Canal type** | **Canal length (m)** | **Q ($m^3$/s) Inflow** | **Q ($m^3$/s) Outflow** | **Q ( m3/s) Average** | **Q (m3/s)** | **Q (l/s)** | **Loss (%)** | **Loss (L/s/m)** | |
| **TC01** | LTC | 225 | 0.285 | 0.246 | 0.269 | 0.039 | 39 | 14 | 0.17 | 86.3 |
| | LTC | 215 | 0.245 | 0.215 | 0.235 | 0.03 | 30 | 12 | 0.14 | 87.6 |
| | LTC | 265 | 0.216 | 0.155 | 0.191 | 0.061 | 61 | 28 | 0.23 | 71.8 |
| | **Average** | **235** | **0.25** | **0.21** | **0.23** | **0.04** | **43.3** | **18** | **0.18** | **81.9** |
| | UTC | 210 | 0.164 | 0.11 | 0.137 | 0.054 | 54 | 39 | 0.257 | 67 |
| | UTC | 200 | 0.096 | 0.056 | 0.076 | 0.04 | 40 | 42 | 0.2 | 58 |
| | **Average** | **205** | **0.13** | **0.083** | **0.1065** | **0.047** | **47** | **40.5** | **0.2285** | **62.5** |
| **TC03** | LTC | 215 | 0.271 | 0.232 | 0.252 | 0.039 | 39 | 14 | 0.18 | 86 |
| | LTC | 198 | 0.221 | 0.179 | 0.202 | 0.042 | 42 | 19 | 0.21 | 81 |
| | LTC | 215 | 0.174 | 0.145 | 0.161 | 0.029 | 29 | 17 | 0.14 | 83 |
| | **Average** | **209.33** | **0.22** | **0.185** | **0.205** | **0.037** | **36.7** | **16.7** | **0.18** | **83.3** |
| | UTC | 200 | 0.143 | 0.098 | 0.121 | 0.045 | 45 | 31 | 0.225 | 69 |
| | UTC | 195 | 0.085 | 0.056 | 0.071 | 0.029 | 29 | 34 | 0.149 | 66 |
| | **Average** | **197.5** | **0.114** | **0.077** | **0.096** | **0.037** | **37** | **32.5** | **0.187** | **67.5** |
| **TC05** | LTC | 235 | 0.098 | 0.069 | 0.0935 | 0.029 | 29 | 30 | 0.12 | 70.4 |
| | LTC | 295 | 0.08 | 0.068 | 0.0805 | 0.012 | 12 | 15 | 0.04 | 85 |
| | LTC | 225 | 0.07 | 0.056 | 0.069 | 0.014 | 14 | 20 | 0.06 | 80 |
| | **Average** | **251.7** | **0.083** | **0.064** | **0.081** | **0.018** | | **21.7** | | **78.5** |
| | UTC | 265 | 0.059 | 0.032 | 0.0455 | 0.027 | 27 | 46 | 0.102 | 54 |
| | | 185 | 0.058 | 0.042 | 0.101 | 0.016 | 16 | | 0.087 | 72.4 |
| | **Average** | 225 | 0.0585 | 0.037 | 0.07275 | 0.0215 | 21.5 | 36.8 | 0.0945 | **63.2** |

**N.B:-**TC (01, 03 &05), Tertiary canal one, three and five in the unit CE, conveyance efficiency, LTC, Lined tertiary canal and UTC, Unlined tertiary canal.

During the field visit the water was leaking from different locations of earthen tertiary canals. The sidewalls were eroded (width was widened) and plants/grasses were growing in the canals and also some of the canal bed slope was also causing backflow when sufficient water was not supplied in the canals that caused of water is stagnate, which decreased flow depth of water and widened the canal widths (Figure 4.2). The reasons behind high conveyance loss of earthen canals in the studied canals were poor management, improper design, rodent's holes, (Rahman et al., 2010) insufficient channel bed slop and overtopping the bank. Large amount of water was lost, which could have irrigated more lands that implies that a significant amount of irrigation water was lost in the earthen canal with compared to lined canals.


Figure 4.1:-Poor canal maintenance

Generally canal conveyance efficiency is affected by different canal types and user application method which is water is rotated from one farmer to the other by means of bund break and some of the earthen canal was affected by roads of the residents (donkey carts), trashes, weed growths which results widened of canal sidewall and makes water become stagnant in the canal that create back flow (Figure 4.2). They use mud, wood and trashes of different plants to obstruct the flow of water and divert it to the next farmer. However, as this mechanism is not quite efficient in obstructing the flow of water, still much water leaks and flows to the undesired canals that reduce the efficiency of canal.

### 4.4.1.2. Water level ratio (WLR)

Water-level ratio indicates the sustainability of the design water level called water delivery performance and was calculating by dividing the volume of water actually delivered(0.4155m$^3$ /s) for command area to the design water level (0.4692m$^3$/s) were computed using equation 3.9 was 0.885. The actual flow discharges where delivered to the command areas was estimated by using float method (equation 3.6) during the main irrigation season (January to April) and take the average flow values of the irrigation season. During flow measurements of the irrigation, the maximum and minimum discharge was measured in February and April (Appendix table 4) were 0.445 m$^3$/s and 0.365m3/s respectively.

The computed percentage water level ratio of the study area was 88.6 %( table 4.4) The reduction (11.4%) of water level from initially design capacity of water level was resulted by a number of factors that observed in the conveyance system. The effects of this reduction water level from the design water level were the conveyance system is not regularly maintained and cleaned which affects the water is not freely flow without obstructions. The design flow of water for Inguti Block/unite was obtained from the design document (MottMacDonald (MMD, 2004) and the actual water flow to the command area was measured using float method during main irrigation seasons mentioned as earlier.

Table 4.4. .Water level ratio(WLR) and Cropped area ratio(CAR)

| Design flow | Measured flow | | | Current irrigated | Planned irrigated | | |
|---|---|---|---|---|---|---|---|
| Q (M3/s) | Q (m3/s) | WLR | WLR (%) | Area (ha) | Area (ha) | CAR | CAR (%) |
| 0.4692 | 0.415 | 0.885 | 88.5 | 368 | 391 | 0.94 | 94 |

**N.B**: WLR: water level Ratio, CAR: cropped area ratio

#### 4.4.1.3. Cropped area ratio (CAR)

Cropped area ratios also known as sustainability of irrigable area (SI) were used as an indicator (parameter) to measure the technical performance of the scheme. In fact, the degree to which the initially planned (irrigated) area of schemes is sustained a years after the implementation of a scheme is an important issue for the success of an irrigation scheme. Sustainability of irrigable land (cropped area ratio) indicates the ratio of the currently irrigated area to the initial planned area. According to the design report document(table 4.4) the intended command area that a scheme were initially planned for irrigated were 391 ha, while the actual irrigated area in a cropping season were 368 ha. Hence, the computed result of CAR was 94 %( table 4.4) were determined by using equation (3.9.3). The irrigated areas of the irrigation scheme were a lower reduction compared with that initially planned irrigation schemes; however the reduction (6%) of command area were due imprudent use, a significant proportion of water is lost on farms and the upstream water users mostly influenced downstream water users which is potentiality of the farms to irrigate and the ability of the scheme water supplied to the farm were insufficient in downstream users. Generally the sustainability of irrigated area of Inguti irrigation unite is relatively highest sustainability of irrigation land value were compared to the planned irrigable areas.

#### 4.4.1.4. Infrastructural Effectiveness (EI)

The study was also focused on the irrigation structural system components well performing to designed schemes. The existing condition of infrastructural effectiveness was inspected and carefully counted as functional and damaged infrastructures in unite. Effectiveness of infrastructure (also called structural performance) were used to quantify maintenance performances to analyze whether the maintenance system is operating as well designed/not that were determined with the ratio of the sum of functional structures to the total structures where exist in the irrigation scheme . In inguti irrigation scheme no more severed infrastructures observed in the secondary and tertiary canals. The total number of structures that were installed in the irrigation scheme was 199, from the total number of structures in the unite 194 structures were currently functional Hence, the value of effectiveness of infrastructure was estimated using equation 3.9.4 to be 96.2 percent (table 4.5).The suggested values of infrastructural effectiveness of the irrigation scheme was good which implies that the maintenance activity of a system was fair.

**Table 4.5. List of Infrastructures and its Performances at the unit**

| **Infrastructures** | | | | | |
|---|---|---|---|---|---|
| **Structures** | **Type** | **Total numbers** | **Functional (working)** | **Un-functional (Damaged)** | **Occurrence problems** |
| Division box | Concert | 26 | 26 | | un-balanced opening |
| Division box shutter | Steel | 26 | 23 | 3 | un-balanced opening |
| Division box culvert | concert &PVC | 26 | 24 | 2 | clogging with sediments |
| Drop Structures | Concert | 91 | 91 | | some of scoring |
| Cross regulator | Steel | 3 | 3 | | |
| Control gate | Steel | 14 | 12 | 2 | un-balanced opening |
| | Total | **186** | **179** | **7** | |
| **All Infrastructural Effectiveness (%)** | | | | **96.2%** | |

## 4.4.2. Farm water management evaluation

Even though, various authors have suggested many performance indicators used for evaluations, 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 field application efficiency, field storage efficiency, distribution uniformity and deep percolation ratio.

### 4.4.2.1. Field water Application efficiency (AE)

Water application efficiency provides a general indication of how well an irrigation system that well performs its primary task of delivering water from the conveyance system to the crop and used to evaluate the relation between the quantity of water furnished at the field inlet and the quantity of water required, and made available for evapo-transpiration by the crop to avoid undesirable water stress in the plants throughout the growing cycle. Farmer's field application efficiencies (Ea) computed using equation (3.8.3) on the three farmers which was selected at head, middle and tile of the scheme.

Before determined application efficiency of a field would be compute depth of water stored in the root zone and applied depth were stated in below (Table 4.6) shows the depth of water stored in the root zone (depth stored) calculated with the soil sample taken from three randomly selected farm plots with recommended depth of crop before and after 24hr irrigation events. This was effective root depth for potatoes were 0-30 and 30-60 cm (FAO) and then the difference were calculated from the greater value to the minimum value which was moisture difference. Secondly percent of soil moisture content in volume basis was taken by multiplying the moisture difference with bulk density of the soil. Thirdly to find the moisture content in depth form percent of soil moisture content in volume basis multiplied by sample taken soil depth .Finally Depth stored or depth of water in the root zone determined by summed up the 0-30 to 30-60 soil depths was presented in (table 4.6) bellow

Table 4.6. Determination of Water stored (retained) depth in the root zone(Ws)

| **Location of field** | **soil depth (cm)** | **Sampling Time** | **Average% of Moisture (Wt base)** | **Moisture Difference (%)** | **Average BD ($g/cm^3$)** | **Moisture content (vole ,base)** | **Root Depth (mm)** | **stored depth (mm)** | **Total stored depth (mm)** |
|---|---|---|---|---|---|---|---|---|---|
| | | | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** |
| | | | | | | **(2*3)** | | **(4*5/100)** | **(sum)** |
| **Head** | 0-30 | BI | 37.5 | 7.28 | 1.23 | 8.96 | 300 | 26.8 | |
| | | AI | 44.78 | | | | | | **38.03** |
| | 30-60 | BI | 37.12 | 3 | 1.24 | 3.72 | 300 | 11.2 | |
| | | AI | 40.12 | | | | | | |
| **Middle** | 0-30 | BI | 33.17 | 8.57 | 1.15 | 9.8555 | 300 | 29.57 | |
| | | AI | 41.74 | | | | | | |
| | 30-60 | BI | 36.12 | 4.7 | 1.25 | 4.175 | 300 | 12.53 | **42.11** |
| | | AI | 39.46 | | | | | | |
| **Tail** | 0-30 | BI | 34.16 | 7.29 | 1.15 | 8.3835 | 300 | 25.15 | |
| | | AI | 41.45 | | | | | | **36.06** |
| | 30-60 | BI | 33.22 | 2.91 | 1.25 | 3.6375 | 300 | 10.91 | |
| | | AI | 36.13 | | | | | | |
| **Average** | | | | | | | | | **38.73** |

Flow measurement of applied water depth pass to the field was measured by using RBC flumes with standard calibrated staff gage readings. RBC flumes were installed at the entrance of irrigation water to the field for the selected farm test plot within keeping the level of flume by water levels to avoid external velocities. The RBC flume has a short trapezoidal section with a contraction inserted in the flume bottom which is a simple and reliable instrument for the measurement of the quantity of irrigation water that flows towards a field channels. The flow measurements was directly read on the calibrated flume stilling well in l/s Vs depth in mm (Appendix figure 2) and carefully recorded the flow values, the time that was taken until the irrigator completed irrigating test plot and the average depth of irrigation water passing through the flume then the total volume of water pass through the field was determine by multiplying of the discharge/flow with time taken. Finally the applied depth of water was determined (table 4.7) by dividing the total volume of water with area of irrigated field.

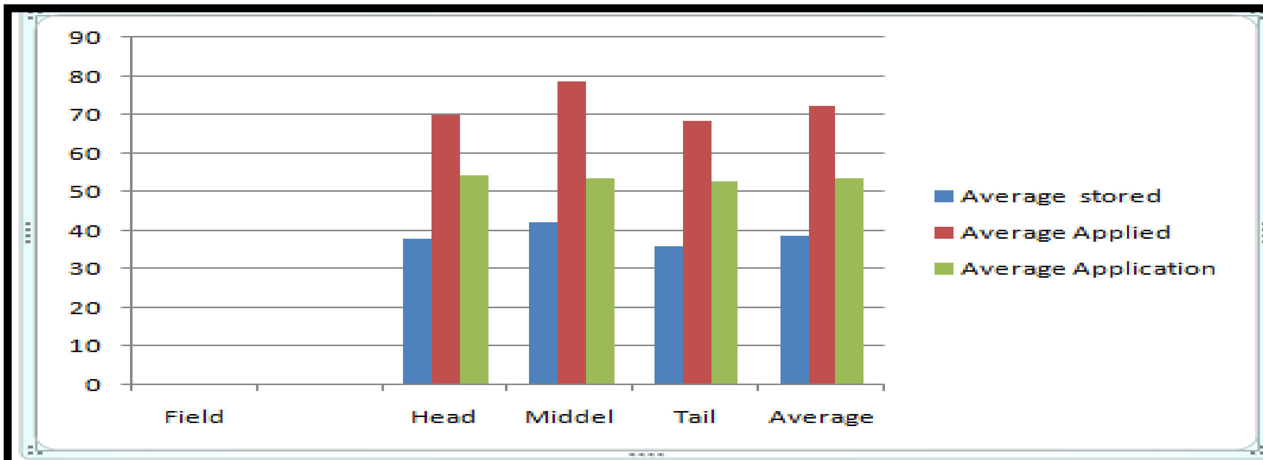
Table 4.7.Average Applied depth of water in (mm)

| **Location of Fields** | **Area ($m^2$)** | **Time (s)** | **Time (Hr)** | **Depth (mm)** | **Q (L/s)** | **Total Volume (Lit)=(5*2)** | **Total Volume ($m^3$)** | **Applied Depth (mm)=(7/1)** |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| **Head** | 1500 | 14200 | 3.94 | 96 | 7.4 | 105080 | 0.0701 | **70** |
| **Middle** | 752 | 9543 | 2.65 | 85 | 6.2 | 59166.6 | 0.0787 | **78** |
| **Tail** | 1115 | 11740 | 3.26 | 88 | 6.5 | 76310 | 0.0684 | **68** |
| | | | | | | | **Average** | **72** |

Applied depth of water in the scheme (table 4.7) shows relatively much water is applied at head of the scheme and lower water is added at the tail of the scheme. Applied depth of water in the unite was 78.68, 70.05 , 68.44 mm at the head, middle and tile of the scheme respectively and the average was 72.39 mm. generally the applied depth of water at middle relatively higher than the other test plots that were applied more water to the crops.

| Table 4.8..Farmers Field Application Efficiency(AE) in each plot | | | |
|---|---|---|---|
| **Location of Field** | **Average stored Depth (mm)=1*2)** | **Average Applied Depth(mm)** | **Average Application Efficiency(%)=(3/4)*100** |
| Head | 38.03 | 70.05 | 54.3 |
| Middle | 42.11 | 78.68 | 53.5 |
| Tail | 36.06 | 68.44 | 52.7 |
| **Average** | **38.73** | **72.39** | **53.5** |

The above (Table 4.8) shows that for three test plots of the (head, middle and tail). The obtained average values of application efficiency were 54.3%, 53.5% and 52.7% for head, middle and tail users respectively the average was 53.5%. This indicates that the application efficiency of the schemes were inefficient from the expected values of surface irrigation due to poor managements of irrigation water to their fields that were applying excess water in the field. Application efficiency of all plots in the schemes was almost similar values that compared from the head farm plots to the tail farm plots. This indicates that those irrigators who are getting water access to crops were not properly managed and over irrigating of the farms that reduce field application efficiency. The 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 (2003) reported that the attainable application efficiency according to the US (soil conservation science) ranges from 55% - 70%, value below this limit would normally be considered unacceptable. Then the schemes were below the recommended values (FAO, 2003) due to weak scheme management activities.




| Field | Average stored depth(mm) | Average Applied Depth(mm) | Average Application Efficiency (%) |
|---|---|---|---|
| | | | |
| Head | 38.03 | 70.05 | 54.3 |
| Middle | 42.11 | 78.68 | 53.5 |
| Tail | 36.06 | 68.44 | 52.7 |
| **Average** | **38.73** | **72.39** | **53.5** |

Graph 4.1. Application efficiency in each test plot

From the graph shows application efficiency all plot were considered as inefficient and indicated that the farmers were applying excess water to their fields in each growth stage. According to (Yusuf, 2004) the application efficiency 30% - 60% was considered as inefficient and indicated that the farmers were applying excess water to their fields. The potential cause of low application efficiency values may be due to the low level of farm water management at the field level.

### 4.2.2. Deep Percolation Ratio

Deep percolation ratio indicates the irrigation applied to a field percolates (field water loss) into the soil below the root zone during application of water to the field. Since the irrigation scheme considered in this study is blocked end furrows, the main source of field water loss was deep percolation. The deep percolation ratio calculated using equation (3.5.5) was 45.7%, 46.5% and 47.3% for head, middle and tail test plots, respectively that were shown in bellow table 4.9.

Table 4.9 Average deep percolation ratio(DPR)

| Field | Ea (%) | RR (%) | DPR (%) |
|---|---|---|---|
| **Head** | 54.3 | 0 | 45.7 |
| **Middle** | 53.5 | 0 | 46.5 |
| **Tail** | 52.7 | 0 | 47.3 |
| **Average** | **53.5** | **0** | **46.5** |

From this result (table 4.9) the deep percolation ratio or high loss due to deep percolation was 47% which was obtained at the middle and tail field of the irrigation scheme because of excess application of water before water depleted from the root zone. A higher deep percolation naturally results lower application efficiency. The averaged scheme loss due to deep percolation was 46.5% that means from the total depth of water applied, 46.5% water was lost due to deep percolations. During the study period it was observed that some irrigators in the middle and tail fields of the scheme were trying to drain out excess water from their fields excavated drainage ditches. Hence, it was an implication of over irrigation which is resulted in water logging problem.

### 4.2.3. Field Storage Efficiency

Storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application. The water storage efficiencies (Es) was computed by monitoring soil moisture before and after irrigations using equation (3.8.5) and the results are shown in ( table 5). The data was used to calculate the required irrigation depth were moisture content at field capacity and permanent wilting point, depletion level and root depth of a crop was used and the required depth of irrigation water was computed by equation(3.8.4)that shown in (table 4.7). Application strategy of refilling depletion fraction at 75% of total soil moisture depletion was considered as recommended by FAO, (Doorenbos and Kassam, 1996).

| Table 5. Average storage Efficiency in each plot | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location of field | Average BD g/cm3 | Average TAW in % | Average TAW | total Root depth mm | depletion factor | Required depth mm | Stored depth mm | Average storage Efficiency % |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | | | | | (1*3*4*5) | | (7/6)*100 |
| Head | 1.245 | 10.505 | 0.105 | 600 | 0.75 | 58.85 | 40.35 | 77.36 |
| Middle | 1.245 | 9.31 | 0.093 | 600 | 0.75 | 52.16 | 47.19 | 80.18 |
| Tile | 1.245 | 8.105 | 0.081 | 600 | 0.75 | 45.41 | 36.06 | 79.41 |
| **Average** | | | | | | 52.14 | 41.2 | 78.98 |

The depth of the water retained in the root zone was computed using moisture content field capacity and permanent wilting point obtained in (Appendixes table 11). The average results of storage efficiency obtained were 63.86%, 75.17% and 77.5% for upstream, middle and downstream locations of the test plots respectively with the average result was 72.2 %. According to Raghuwanshi & Wallender, (1998), the recommended storage efficiency is 87.5% ,Tedla (2007) at Bullinegero small scale irrigation scheme which was 92.8%.  And depending on weather, type of soil and time span considered, storage efficiency might be as high as 90% (FAO,1992. Thus, the storage efficiency of the system is below the recommended value. Generally, the irrigation system was not adequate in fulfilling the soil moisture. This was due to low frequency of water applied to all field and the water was infiltrated deeper. It shows over irrigation of the field and this might be associated with the intention of the farmers on high return from high irrigation depth.

## 4.3. Overall Scheme efficiency

The overall efficiency of the scheme is the ratio of water made available to the crop to the amount released at the source. On the other hand, it is the product of conveyance efficiency and application efficiency. In the present study the overall efficiencies of the irrigation schemes were found to be 46.3 %. The overall efficiency of the Inguti irrigation scheme was within the range of values (40-50

%) commonly observed in other similar African irrigation schemes (Savva & Frenken, 2002). According to FAO, (1989),the irrigation efficiency of the plan 50-60 % is good; 40 % reasonable, while the irrigation efficiency of the plan by 20-30 % is considered poor. It should be conduct in mind that the above values are only indicative values. Therefore the result of overall irrigation scheme (46.3%) is between under reasonable values (FAO, 1989).

## 4.4. Crop and Irrigation water requirements

Crop water requirements are defined as the depth of water needed to meet the water loss through evapo-transpiration. The results indicated that the seasonal crop and irrigation water requirement of potato which computed by CROPWAT 8. computer software during planted at the beginning of initial growing period (January until harvested of the late growing period (May) was estimated at 425.4mm and 336.3mm respectively (Appendix table 5).Average water requirement of potato during the initial, developmental, mid-season and late-season stages accounted for 5.3%, 22.6%, 41.7% and 30.4%, respectively, of the seasonal water requirement of the crop. The crop had the highest crop and irrigation water requirement during developmental stage (Appendix table 5). Crop coefficient (Kc), maximum root depth (m), crop height, yield reduction factor (Kc) values were adopted from FAO Irrigation & Drainage paper 24 and 56, the detailed values in growth stage based which was used to as input values of CROPWAT. The values of in the growing period are represented by crop coefficient curve, the values varies in the growing period. The CROPWAT 8.0 model required the three coefficients of (initial, development and late stages).

## 4.5. Evaluation of Institutional Arrangements and Scheme Support Service

### 4.5.1. Water user association in the unit

A WUA is a beneficiary-based organization that aims to manage the irrigation system for its members without profit basis. Most of WUA arrangements are based on the blocks that is water easily reach to farm areas. The team of WUA selected by the beneficiary of irrigation and organized as irrigation committee or leaders. There are 50 teams organized in Inguti irrigation unites that lead to irrigation scheme facilitation activates. The number of beneficiaries within each team ranges from 16-50 which has a leader. As observed and intervened of the users, involvement of leaders are week for the role of problem solving and managerial issues related to irrigation secluding and or locally called Worrefa. Although, Amhara regional cooperative promotion regional office clearly stated by law that WUA is responsible for water distribution, system maintenance, assessment and collection of irrigation water fees, input supplies, credit facilitation, planning and monitoring, etc. In this regard, the establishment and implementation of independent WUAs to manage water and maintenance are of paramount importance in all small-scale irrigation schemes. The proclamation (No.239/2016) by the regional Water Resource Bureau, which was used to establish and implement WUA, is applicable to the constructed and to-be-constructed irrigation infrastructures (ANRS, 2016). The association will have its own structural leadership (chairman, secretary, treasure) and will produce workable bi-laws to which they stick in the role of the development. The leaders locally called “Yewuha Abats” would be organized based on the way of water delivery systems to each farm unit and also it accountable for the chairman of the association .The farmers laid in one primary and secondary canal will have one “Yewuha Abats  who are responsible for managing his/her member within a farm block. Therefore, the numbers of” water fathers” are depending up on the number of primary and secondary canals which are deliver water to unite (one “Yewuha Abats” per primary or secondary canal).

All members of WUA have two meeting times per a year where all members have a chance to participate and raise outstanding issues for discussion and decision made on time in relation to water fees, distribution systems, conflict resolutions, water managements etc. Payment of annual water fee from all water users is the main source of income for the association. Each beneficiary of the irrigation scheme is expected to pay an annual water use fee. Currently, users pay 30 birr/ha for water use. Inguti irrigation scheme is mainly administered by “Yewuha Abats” or “water fathers” who are elected by the beneficiaries of the scheme. However during the study period Inguti irrigation scheme /unite has weak WUA and it was administered by community representatives or leaders also called "Father of water". The WUA within unite was established 10 years ago but now it is not well functional. This might cause poor sense of ownership, improper irrigation water operation and management and also lack effective communication between the WUA/leaders and users of the scheme.

Generally, regularly meeting were not held at the begging of irrigation scheme operation to scheme managements and there is poor recording systems related to attendance of participant/users, maintenance planning, meeting schedule and reporting to irrigation managerial authority/stakeholders. The key informants 25 households also revealed that the WUA‟s management committee has not been effective in conducting planned meetings (monthly, yearly) which affected their contributions of managerial authority and control of activities of the leaders task implementation, specially allocation and distribution of water to a farm , awareness creation and mobilization of free labor for canal maintenance activities (de-silting, weeding, cleaning,) and resolving conflict among water users and punishing offenders according to the fines prescribed by bylaws.

### 4.5.2. Organizational structures of WUAs

The Koga large scale irrigation scheme water users association was established in 2010 within all irrigation units/blocks. Inguti small scale irrigation scheme is one of the blocks in Koga large scale irrigation scheme In Inguti small scale irrigation scheme the water user association was initially establish in cooperative forms as a multipurpose for local institution with main objectives, scheme operation and maintenance, input and credit supply, disputes conflicts and marketing of out puts. With regard to organizational modality of the target groups, they need to be organized in to associations can be called" Water users association" in which both private and communal owner ship and responsibilities are simultaneously involved. Every member grows the selected varieties of crops on its own plots in fact, according to the technical recommendations and rated of applications recommended by the development extension service (DAs) with close follow up and monitoring. However, scheme management and water utilization related issues are administered by the water user associations who's give car the common resources in the scheme and develop its own managerial structures of water user association that suit for irrigation scheme managements . Generally the WUA structures have executive committee, sub-committee and water user teams for better implementation of operation and maintenance activities at irrigation system and distribution levels. An Executive Committee consisting of seven members in each irrigation system is responsible for operation and maintenance of the irrigation systems. With a composition of different WUA committee members (chairman and vice chairman, a secretary, control and monitoring committee, cashier).

### 4.5.3. Performance of the water user association

The strength of WUA measured and evaluated by the accomplishments of scheme maintenance and management activities within an irrigation scheme fully covered own responsibility that assigned by the users. Irrigation scheme have a number of infrastructures that used to facilitate irrigation activities and improve its performances that were need to sense of ownership of that irrigation property within users. Therefore, WAU have great responsible for creating awareness to its members of users, mobilizing for maintenance and managerial activates and to disseminate irrigation infrastructure as a single property for users, to provide an incentive for organizational irrigation that effectively manage its members. As mentioned earlier, the WUA includes rules issued by all cooperatives/members. The first problem associated with communicative practice is the fundamental principle that unions are organized, all members must be voluntary. Farmers share the same type of irrigation water, sometimes organizing the association, making the cooperative work effective in irrigation water management. The feeling of respondents about performance of water user association within the irrigation unite are stated in bellow table (table 4.5.1) which asked by well prepared questions for 55 total respondents/farmers in the unit.

Table 4.5.1. What do you feel/think the performance of WUA Committee in scheme managements(water distribution, operations, maintenances and on time dispute resolving mechanisms)

| Response of respondents/Farmers about WUA performances | | Frequency | Percent (%) |
|---|---|---|---|
| 1 | Very Good | 4 | 7 |
| 2 | Good | 7 | 13 |
| 3 | Medium | 13 | 24 |
| ***4** | **Poor** | **31** | **56** |
| 5 | Total | 55 | 100 |

From the above table 4.5.1 shows that 56% of the respondent responded that the overall performance of the Water Users Association in terms of managing the schemes was poor and water user associations are not well organized structures and the range is to be weak to run the irrigation schemes facilitations that improve the performance of irrigations at the unite. Moreover, the cooperative committee manual lacks detailed operational guidelines and rules (such as entry, allocation, penalty, input rules) and organizational structure specify that in the irrigation scheme.

Poor supervision and non-existence of irrigation schedules, by the management committee, made it impossible for a good number of users to irrigate their fields at regular intervals (frequency). Farmers mostly sense for satisfaction by over irrigate (occurrence of excess water on farm) and not to their knowledge about the volume of water needed for a crop which is called crop water requirement.

These definitely affected the performance since the success of irrigation to poverty alleviation, according to Bhattarai et al., (2002), depends on water management, input utilization, access to potential output market and socio economic characteristics of users.

### 4.5.4. Extension services and training

Extension services and trainings by the Gos/NGos is one of capacity building in relation with irrigation water applications, conflict resolutions, scheme maintenances and operations to the users/farmers that used to enhance the knowledge and attitudes of farmers about how to irrigate and manage scheme infrastructures for improving of overall irrigation performances. The provision of agricultural extension services in Inguti irrigation schemes mostly contribute with advising of agronomist activates to enhance yields of the crop but the mobilization and trainings in maintenance and operation irrigation infrastructures for farmers were a little experience in operation and maintenance of scheme infrastructures.

**Table 4.5.2. Response of farmers in relation to extension service and trainings get from GOs/NGos**

| Response of respondents/Farmers to get | | Trainings Frequency | Percent (%) |
|---|---|---|---|
| 1 | Yes | 21 | 38 |
| ***2** | **No** | **34** | **62** |
| 3 | Total | 55 | 100 |

Potential benefit that the scheme could provide to the beneficiary farmers and the local community, a qualified extension agent would have been great role that enhance scheme performances with mobilizing of farmers in operation and maintenance activities of the schemes. It was, however, farmers were not getting scheduled advice from an irrigation agronomist or from a qualified development agent critically. As shown above tables 4.2 most of farmers responded that (34%) were no get trainings and extension services from governments and other respondents get some of training by development agents(DAs) for the selected model framers /users at the unit. The training, they said, was offered by Merawi Woreda and Keble level administrative councils are expected committed mobilize the community, support the water users association (WUA) and provide administrative supports in the course of the development. But most of the trainees that given by development agents were members of the WUA and some selected model farmers.

Table 4.5.3. Responds of Farmers about, what supporting services to get from GOs/NGos

| Responses about What kind of support service get from GOs? | | Frequency | Percent (%) |
|---|---|---|---|
| 1 | Infrastructural support | 5 | 9 |
| ****2** | **Technical support/advice** | **16** | **29** |
| ***3** | **Input supply for irrigation** | 22 | **40** |
| 4 | Maintenances | 5 | 9 |
| 5 | No Support | 7 | 13 |
| 6 | Total | 55 | 100 |

Irrigation activities critically need different supporting services that facilitate scheme users to easily and properly operate the scheme infrastructures to provide irrigation performances and efficiencies which obtained from the governments. Table 4.3: states that, the Response of farmers to the kind of support they got from the government. Most of respondents responded (40%) that to have got input supply support and 29% of respondents responded that to got technical advice for farmers when to irrigate and how to irrigate for different crop varieties with relation to field water application. On the other hand, 13% of them responded that they have no got support on the government.

### 4.5.5. Scheme Management problems

Managerial problems in irrigation scheme were highly affecting the performances of irrigations that structured from irrigation authority to WUA/beneficiaries in relation with institutional arrangements/setups towards the issue prevention mechanisms by authority level or WUA levels. In general management problems in the irrigation unite stated in bellow tables 4.4 and responded by the farmers/users.

Table 4.5,4. Responds of Farmers about, what factors that influencing the success of WUA in relation to scheme irrigation managements.

| Responses of farmers/users | | Frequency | Percent (%) |
|---|---|---|---|
| *1 | **Lack of cooperation/integrity** | **21** | **38** |
| 2 | Transparency and accountability | 15 | 27 |
| 3 | Workload | 7 | 13 |
| 4 | Low income | 4 | 7 |
| 5 | Absence of Training | 8 | 15 |
| 6 | Total | 55 | 100 |

The results in above table 4.5.4 indicated that there is lack of cooperation/integrity between WUAs and other institutions working in Inguti irrigation unite. This constitutes the major factor influencing WUAs participation in Inguti irrigation scheme management. Lack of transparency between WUAs and other institutions from one hand and between WUAs and their members from other hand constitutes real problem in irrigation scheme. Lack of transparency between WUAs members comes from the low educational level of the members due to absence of trainings. Low income from agriculture which associated with small landholding farms has been minimally influence the performance of WUAs.

In general in Ingutie small scale irrigation schemes management problems were observed and interviewed at a scheme levels were include Lack of an efficient WUA, Water management problems, such as equitable water use, high water loss due to seepage as a result of a poor maintenance strategy, uncontrolled water use, vandalism and water theft, Scheme management issues, such as lack of structural maintenance, lack of proper operation of the structures and lack of the ownership sense are the major constraints in all schemes . The result shows that the irrigation systems were poorly managed in terms of water allocation and distribution, conflict management and system maintenance, because of lack of well-established organizational and institutional conditions. The water user associations are not well organized and found to be weak to run the irrigation scheme.

### 4.5.6. Water distribution and conflict management

Water User Association of the scheme is not well-organized; they have been the management gaps/problems were rise disputes between the user and farmers. Applying fair water distribution in the system, avoiding traditional water division structures and applying a gated division system might enhancing water distribution capacity of the canals vital for improve proportionality of irrigation water distribution system that is used to resolving conflicts among users in the irrigation scheme. Water distribution systems of the schemes were scheduled and decide by the beneficiary that stated in bellow tables rated from the respondents.

Table 4.5.5. Responds of Farmers about, Water distribution schedules in the scheme

| Who decides irrigation scheduling?(when and how much) to irrigate | | Frequency | Percent (%) |
|---|---|---|---|
| 1 | Water User Association(WUA) | 8 | 15 |
| ***2** | **Scheme Beneficiary /users** | **21** | **38** |
| 3 | Development Agent(DAs) | 5 | 9 |
| 4 | Keble Administration | 11 | 20 |
| 5 | Irrigation Committee(IC) | 10 | 18 |
| 6 | Total | 55 | 100 |

The water distribution in the scheme is managed by the beneficiaries themselves without designed irrigation schedule were considered based on crop water demand and each growth stages. The result shown that only 15 % of the respondent farmers confirmed that water supply to each farmer is decided by WUA and 38% farmers confirmed that the distribution was managed by beneficiary households (Table 4. 5). The household with the rotation water distribution system will use the water for that day until he/she completes irrigating the fields. The beneficiaries in the scheme do not know in advance when they will get water. According to all respondents, every member in the scheme has the right to get irrigation water and is free to grow a crop he/she wishes but farmers not to know the specific time for irrigating and water up taking to farm within irrigation time of 12hr.

Conflict among the irrigation users were obvious in irrigation schemes due to the reason of water abstraction for different purpose that diverted to the command areas. The common source of conflict that rise in the scheme responded by the scheme farmers stated in bellow tables.

Table 4.5.6. Responds of Farmers about, source of conflicts in the scheme

| What is the common sources of conflict in the scheme | | equency | percent (%) |
|---|---|---|---|
| 1 | Scarcity of Water | 4 | 7 |
| 2 | Water theft | 11 | 20 |
| 3 | Land shortage | 3 | 6 |
| 4 | Poor irrigation scheduling | 15 | 27 |
| **5** | **Unequal water distribution/Mgt** | **22** | **40** |
| 6 | Total | 55 | 100 |

40 % percent of household respondents believe that the conflict is due to the problem of water management which is lack of responsible body to control the water distribution system and other conflicts were raised due improper irrigation schedules, water theft that included poor water management activities stated in above (Table 4.5). According to the interviews and observation of households the outstanding conflicts in irrigation scheme was resolved by the beneficiary/users.

## 4.5.7. Operation and maintenance problems

All operation and maintenance activities in the irrigation schemes are coordinated by WUAs committees. The Water committee is responsible for the mobilization of resources required for maintenance activities and for the scheduling of maintenance of the primary, secondary and tertiary canals. Maintenance activities within a block covering small areas are done by the block or team members and coordinated by the team leaders. Besides interview, field visit was done to collect data like up-keeping of irrigation structures, efficiency of irrigation water utilization, feeling and attitude of beneficiary farmers, water distribution and water uses etc. The governments give the operation and maintenance responsibility to users, but the users did not a work any operation and maintenance activity. However, the irrigators clean annually by removing canal sediment and weed.

Table 4.5.7. Responds of Farmers about, Serious Technical problems in the scheme

| What factor influence poor maintenance of irrigation infrastructures | | Frequency | Percent (%) |
|---|---|---|---|
| 1 | Sedimentation of canal | **23** | **42** |
| 2 | Canal seepage | 17 | 31 |
| 3 | Infrastructural damage/loss | 8 | 14 |
| 4 | Canal branching | 7 | 13 |
| 6 | Total | 55 | 100 |

The above result shown that 42% of respondents reported that problems exist in the irrigation canals were deposition of sedimentation due to poor cleaning of the canals that the cause of weed invasion in the canal beds and 31% of the respondents responded that the problems occurred in the canals were seepage loss due to cracking of concrete line canals and long time stagnate water in earthen canals.

Table 4.5.8. Responds of Farmers about, why poor maintenance of irrigation canals in the scheme

| What factor influence for poor maintenance of irrigation infrastructures(Canal maintenance) | | Frequency | Percent (%) |
|---|---|---|---|
| 1 | Poor working integrity/organization | 24 | 44 |
| 2 | Insufficient finical support | 16 | 29 |
| 3 | poor performance of WUA | 9 | 16 |
| 4 | Others | 6 | 11 |
| 6 | Total | 55 | 100 |

The Responses of farmers shown that for poor maintenance of the canals due to poor work collaboration/integrity that mobilizing and facilitating the scheme users. However, the status of the secondary canals and their water control structures showed that no proper maintenance has been carried out for a long time and the cooperative was not effectively shouldering the scheme management. The beneficiary farmers also acknowledged that the scheme was poorly maintained, and they attributed the problem to lack of fund and poor organization for maintenance.

# CHAPTER FIVE

# 5. Summery and Conclusion

## 5.1. Summery

Assessing farm water managements and performances of infrastructures is critical to evaluate the existing situations of farm water management and the levels of infrastructural performances. Evaluation of farm water management and infrastructural performance was conducted using the internal performance indicators. The selected internal performance indicators computed were conveyance efficiency, field irrigation application efficiency, storage efficiency, water level ratio, Infrastructural effectiveness and overall efficiency.

The averaged water conveyance efficiency for lined secondary and tertiary canal was found to be 86.5% and 81% respectively and about 64% of water conveyance efficiency for unlined tertiary canals. The results imply that conveyance efficiency of the scheme was below the recommended values 95%for lined canals while 80 % unlined canals for clay soil (FAO, 1989), (Wachyan & Rushton, 1987). According to the result, most conveyance loss was observed in tertiary canals due to poor managements of canals, eroding off the canal, insufficient bed slop of the canal (backflow), leakage due to cracking, weed growing in the canals and illegal water abstraction.

According to the result most of infrastructures in the irrigation scheme at tertiary level was well functional and its infrastructural performance was 96%.But some of infrastructures at the unit was un-functional due to sediment clogging of division box culvert, unbalanced opening of some gates and damaging of gate shutters which means the gat is not to allow pass the required amount of water in the field.

From the results, the averaged irrigation application efficiency was 53.5 which indicate inefficient field water managements due to excessive application of irrigation water. This field irrigation application efficiency is below the standard of 60% for surface irrigation methods (Abera et al. 2019). The reason for lowering of field application efficiency were the farmers sense the crops is productive by applying excess waters that leads to the crop were not get the required waters based on the growth stages.

According to the results, the beneficiary participation the irrigation schemes in canal clearing and regular maintenance was low due to poor performance of WUAs that facilitate and solve scheme managerial issues effectively and timely. The UWA lacks to conduct regular meeting and scheduling of activities for the effective operation of the irrigation scheme. There is also poor documentation and attendance of participant/users, maintenance planning and reporting to irrigation managerial authority. Due to weak performances of WUAs, some of the canals were covered by weeds, side wall eroding and deposition of sediments which allows irrigation water was spill out and lost.

## 5.2. Conclusion

- ✓ Assessing of the performance of irrigation infrastructures and farm water managements will help to understand the present status of these scheme management levels. Therefore, regular performance evaluation study is imperative.
- ✓ Canal lining would minimize conveyance losses and increase available water to beneficiaries.
- ✓ Canals, especially secondary and tertiary canals require continuous cleaning and maintenance to keep them free from weeds and reduce the depositions of silts in the canals that increase conveyance efficiency. The upstream catchment treatment would reduce canal as well as infrastructures sedimentation and hence improve the performance of the scheme.
- ✓ WUA and the beneficiaries" farmers should work together in coordination with each other. Strengthening the existing "water user association" and building their capacity would improve the performance.
- ✓ Putting formal way of fee collection and utilizing the collected money for maintenance work are relevant to increase farmer's participation. Charging the farmers as per amount of water to supply may be examined. This might be reduce over watering of irrigation fields due payments per applied of waters. Farmers should minimize much depth of irrigation water they were applied at the time of irrigation to improve field application efficiency and overall field water managements of the scheme.
- ✓ Institutional support and continuous monitoring and evaluation of the scheme are necessary to provide feedback information important for the future planning of management of new schemes and maintenance of old ones. Water user association of the scheme is not well-organized; they have been the management gaps. So, reforming or giving training to them is essential for ensuring healthier water management, fair distributing of irrigation water, resolving conflicts among users in the irrigation scheme.
- ✓ Irrigation infrastructures should be maintained and keep from stolen, clogging with trashed materials, animal contact and immediately replaced the damaged infrastructures. Currently farmers in Inguti

irrigation scheme are simply practicing the tilling furrow irrigation system, not functional furrow system used as a flood system. The agronomists should give the strength of the users on the irrigated area within appropriate furrow dimensions based on the crop type.

- ✓ To develop awareness of farmers that regularly clean and removed all mud, debris and vegetation from unlined canals; farmers must be able to do that on a rotational basis because it's for their own benefit.
- ✓ Experience sharing from one irrigation scheme to another's and Training of farmers is crucial for better application efficiency, canal clearing and available field water management.

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# List of Appendixes

## Appendix1:- Tables

Appendix Table 1: Average soil moisture content before and 24hr after irrigation event in the unite

| | | **Location of Field and Depth(cm)** | | | | | |
|---|---|---|---|---|---|---|---|
| **Stage** | **Soil Moisture Weight base (%)** | **Head** | | **Middle** | | **Tile** | |
| | | **0-30** | **30-60** | **0-30** | **30-60** | **0-30** | **30-60** |
| **Initial stage** | BI(%) | 35.06 | 37.32 | 38.06 | 38.32 | 35.07 | 33.52 |
| | AI(%) | 42.13 | 41.07 | 41.13 | 41.08 | 41.03 | 36.58 |
| | | | | | | | |
| **Dev:t Stage** | BI(%) | 33.51 | 35.12 | 36.51 | 36.12 | 34.51 | 31.42 |
| | AI(%) | 42.04 | 40.16 | 44.05 | 39.06 | 42.24 | 34.56 |
| | | | | | | | |
| **Late Stage** | BI(%) | 30.93 | 35.92 | 37.93 | 36.91 | 32.94 | 34.73 |
| | AI(%) | 41.06 | 41.22 | 46.05 | 40.22 | 41.08 | 37.24 |

Appendix table 2. Average Soil Bulk Density gcm-3 n=9

| **Location of Fields** | **Depth (cm)** | **Bulk density (g/cm3)** | | | **Average Bulk density (g/cm3)** |
|---|---|---|---|---|---|
| **Head** | 0-30 | 1.15 | 1.13 | 1.17 | 1.15 |
| | 30-60 | 1.26 | 1.24 | 1.25 | 1.25 |
| **Middle** | 0-30 | 1.21 | 1.26 | 1.21 | 1.23 |
| | 30-60 | 1.28 | 1.20 | 1.24 | 1.24 |
| **Tile** | 0-30 | 1.13 | 1.16 | 1.15 | 1.15 |
| | 30-60 | 1.27 | 1.23 | 1.25 | 1.25 |
| | **Average** | | | | **1.21** |

Appendix Table 3: Soil Texture, Bulk density, Field capacity, Wilting point and Total available water

| **Field** | **soil depth** | **PH** (H2O) | **Particle size distribution (%)** | | | **soil textural class** | **Bulk density (g/cm³)** | **FC (%)** | **PWP (%)** | **TAW (%)** | **TAW (mm)** | **TAW (mm/m)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Send | Silt | Clay | | | | | | | |
| **Head** | 0-30 | 4.76 | 9 | 15 | 76 | Heavy Clay | 1.15 | 26.88 | 16.79 | 10.09 | 34.81 | 116.04 |
| | 30-60 | 4.98 | 17 | 19 | 64 | Heavy Clay | 1.25 | 26.75 | 16.64 | 10.11 | 37.91 | 126.38 |
| **Middle** | 0-30 | 4.71 | 17 | 21 | 63 | Heavy Clay | 1.23 | 27.35 | 18.05 | 9.3 | 34.32 | 114.39 |
| | 30-60 | 4.84 | 9 | 25 | 66 | Heavy Clay | 1.24 | 27.23 | 17.91 | 9.32 | 34.67 | 115.57 |
| **Tile** | 0-30 | 4.72 | 13 | 25 | 62 | Heavy Clay | 1.15 | 25.14 | 17.29 | 7.85 | 27.08 | 90.28 |
| | 30-60 | 4.89 | 11 | 15 | 74 | Heavy Clay | 1.25 | 24.95 | 16.59 | 8.36 | 31.35 | 104.50 |
| **Average** | | **4.82** | **12.7** | **20** | **67.5** | **Heavy Clay** | **1.22** | **26.4** | **17.2** | **9.2** | **33.36** | **111.19** |

Appendix table 4. Average monthly flow discharges in the scheme

| **Month** | **Q ( M3/s)** | **Q (L/s)** |
|---|---|---|
| January | 0.424 | 424 |
| February | 0.445 | 445 |
| March | 0.428 | 428 |
| April | 0.365 | 365 |
| **Average** | **0.4155** | **415.5** |

Appendix table 5 Crop water requirement and irrigation water requirement

Crop Water Requirements

ETo station: Bahir Dar | Crop: Potato

Rain station: Bahir Dar | Planting date: 06/01

| Month | Decade | Stage | Kc | ETc | ETc | Eff rain | Irr. Req. |
|---|---|---|---|---|---|---|---|
| | | | coeff | mm/day | mm/dec | mm/dec | mm/dec |
| Jan | 1 | Init | 0.50 | 1.50 | 7.5 | 0.6 | 6.9 |
| Jan | 2 | Init | 0.50 | 1.51 | 15.1 | 0.0 | 15.1 |
| Jan | 3 | Deve | 0.50 | 1.58 | 17.4 | 0.2 | 17.2 |
| Feb | 1 | Deve | 0.64 | 2.08 | 20.8 | 2.8 | 18.0 |
| Feb | 2 | Deve | 0.85 | 2.87 | 28.7 | 4.0 | 24.7 |
| Feb | 3 | Deve | 1.04 | 3.67 | 29.3 | 4.2 | 25.1 |
| Mar | 1 | Mid | 1.13 | 4.17 | 41.7 | 4.1 | 37.6 |
| Mar | 2 | Mid | 1.13 | 4.33 | 43.3 | 4.3 | 39.1 |
| Mar | 3 | Mid | 1.13 | 4.38 | 48.2 | 5.8 | 42.4 |
| Apr | 1 | Mid | 1.13 | 4.43 | 44.3 | 6.2 | 38.1 |
| Apr | 2 | Late | 1.11 | 4.39 | 43.9 | 7.0 | 36.9 |
| Apr | 3 | Late | 0.99 | 3.85 | 38.5 | 13.5 | 24.9 |
| May | 1 | Late | 0.85 | 3.27 | 32.7 | 21.0 | 11.6 |
| May | 2 | Late | 0.75 | 2.83 | 14.1 | 13.5 | 0.6 |
| | | | | | **425.4** | **87.1** | **338.3** |

Appendix Table 6: ETO values of the irrigation scheme.

Monthly ETo Penman-Monteith - E:\eto.PEM

Country: Ethiopia | Station: Bahir Dar

Altitude: 1800 m. | Latitude: 11.59 °N | Longitude: 37.38 °E

| Month | Min Temp | Max Temp | Humidity | Wind | Sun | Rad | ETo |
|---|---|---|---|---|---|---|---|
| | °C | °C | % | km/day | hours | MJ/m?/day | mm/day |
| January | 7.8 | 27.5 | 43 | 1 | 9.5 | 20.8 | 3.02 |
| February | 10.1 | 29.5 | 40 | 1 | 9.5 | 22.3 | 3.39 |
| March | 12.8 | 30.2 | 40 | 1 | 9.1 | 23.1 | 3.83 |
| April | 10.3 | 30.6 | 40 | 1 | 9.2 | 23.7 | 3.95 |
| May | 15.8 | 29.6 | 40 | 1 | 8.1 | 21.7 | 3.77 |
| June | 13.9 | 28.5 | 56 | 1 | 6.9 | 19.6 | 3.62 |
| July | 14.4 | 24.7 | 67 | 1 | 4.9 | 16.7 | 3.11 |
| August | 14.3 | 25.2 | 76 | 1 | 4.8 | 16.7 | 3.14 |
| September | 14.0 | 26.2 | 88 | 1 | 6.5 | 19.1 | 3.59 |
| October | 13.8 | 27.0 | 74 | 1 | 8.6 | 21.3 | 3.77 |
| November | 11.6 | 27.1 | 65 | 1 | 9.3 | 20.8 | 3.37 |
| December | 12.6 | 27.8 | 58 | 1 | 7.9 | 18.1 | 2.95 |
| **Average** | **12.6** | **27.8** | **57** | **1** | **7.9** | **20.3** | **3.46** |

**Appendix Table 7: Secondary canal conveyance loss and conveyance efficiency in the unit.**

| | | **Average Q in m3/s** | | | **Conveyance loss** | | | | **Conveyance Efficiency ( %)** |
|---|---|---|---|---|---|---|---|---|---|
| **Canal type** | **Canal Length (m)** | **Q in ($m^3$/s) Inflow** | **Q in ($m^3$/s) Outflow** | **Q ($m^3$/s)** | **Q ($m^3$/s)** | **Q (l/s)** | **Loss (%)** | **Loss (L/s/m)** | |
| LSC | 325 | 0.415 | 0.335 | 0.375 | 0.08 | 80 | 19.1 | 0.25 | 80.7 |
| USC | - | - | - | - | - | - | - | - | - |
| LSC | 251 | 0.334 | 0.282 | 0.308 | 0.052 | 52 | 16.4 | 0.21 | 84.4 |
| USC | - | - | - | - | - | - | - | - | - |
| LSC | 165 | 0.281 | 0.246 | 0.264 | 0.035 | 35 | 12.5 | 0.21 | 87.5 |
| USC | - | - | - | - | - | - | - | - | - |
| **Average** | | | | | | **55.7** | | **0.22** | **84.2** |

**Appendix table 8: Tertiary canal conveyance loss and conveyance efficiency in the unit.**

| | Q in m3/s | | | | | Conveyance loss | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Canal code** | **Canal type** | **Canal length (m)** | **Q ($m^3$/s) Inflow** | **Q ($m^3$/s) Outflow** | **Q ( m3/s) Average** | **Q (m3/s)** | **Q (l/s)** | **Loss (%)** | **Loss (L/s/m)** | **CE (%)** |
| **TC01** | LTC | 225 | 0.285 | 0.246 | 0.269 | 0.039 | 39 | 14 | 0.17 | 86.3 |
| | LTC | 215 | 0.245 | 0.215 | 0.235 | 0.03 | 30 | 12 | 0.14 | 87.6 |
| | LTC | 265 | 0.216 | 0.155 | 0.191 | 0.061 | 61 | 28 | 0.23 | 71.8 |
| | **Average** | **235** | **0.25** | **0.21** | **0.23** | **0.04** | **43.3** | **18** | **0.18** | **81.9** |
| | UTC | 210 | 0.164 | 0.11 | 0.137 | 0.054 | 54 | 39 | 0.257 | 67 |
| | UTC | 200 | 0.096 | 0.056 | 0.076 | 0.04 | 40 | 42 | 0.2 | 58 |
| | **Average** | **205** | **0.13** | **0.083** | **0.1065** | **0.047** | **47** | **40.5** | **0.2285** | **62.5** |
| **TC03** | LTC | 215 | 0.271 | 0.232 | 0.252 | 0.039 | 39 | 14 | 0.18 | 86 |
| | LTC | 198 | 0.221 | 0.179 | 0.202 | 0.042 | 42 | 19 | 0.21 | 81 |
| | LTC | 215 | 0.174 | 0.145 | 0.161 | 0.029 | 29 | 17 | 0.14 | 83 |
| | **Average** | **209.33** | **0.22** | **0.185** | **0.205** | **0.037** | **36.7** | **16.7** | **0.18** | **83.3** |
| | UTC | 200 | 0.143 | 0.098 | 0.121 | 0.045 | 45 | 31 | 0.225 | 69 |
| | UTC | 195 | 0.085 | 0.056 | 0.071 | 0.029 | 29 | 34 | 0.149 | 66 |
| | **Average** | **197.5** | **0.114** | **0.077** | **0.096** | **0.037** | **37** | **32.5** | **0.187** | **67.5** |
| **TC05** | LTC | 235 | 0.098 | 0.069 | 0.0935 | 0.029 | 29 | 30 | 0.12 | 70.4 |
| | LTC | 295 | 0.08 | 0.068 | 0.0805 | 0.012 | 12 | 15 | 0.04 | 85 |
| | LTC | 225 | 0.07 | 0.056 | 0.069 | 0.014 | 14 | 20 | 0.06 | 80 |
| | **Average** | **251.7** | **0.083** | **0.064** | **0.081** | **0.018** | | **21.7** | | **78.5** |
| | UTC | 265 | 0.059 | 0.032 | 0.0455 | 0.027 | 27 | 46 | 0.102 | 54 |
| | | 185 | 0.058 | 0.042 | 0.101 | 0.016 | 16 | | 0.087 | 72.4 |
| | **Average** | 225 | 0.0585 | 0.037 | 0.07275 | 0.0215 | 21.5 | 36.8 | 0.0945 | **63.2** |

**Appendix Table 9.Water level ratio (WLR) and Cropped area ratio (CAR**

| Design flow Q (M3/s) | Measured flow Q (m3/s) | WLR | WLR (%) | Current irrigated Area (ha) | Planned irrigated Area (ha) | CAR | CAR (%) |
|---|---|---|---|---|---|---|---|
| **0.4692** | **0.415** | **0.885** | **88.5** | **368** | **391** | **0.94** | **94** |

**Appendix table 10. List of Infrastructures and its Performances at the unit**

| **Infrastructures** | | | | | |
|---|---|---|---|---|---|
| **Structures** | **Type** | **Total numbers** | **Functional (working)** | **Un-functional (Damaged)** | **Occurrence problems** |
| Division box | Concert | 26 | 26 | | un-balanced opening |
| Division box shutter | Steel | 26 | 23 | 3 | un-balanced opening |
| Division box culvert | concert &PVC | 26 | 24 | 2 | clogging with sediments |
| Drop Structures | Concert | 91 | 91 | | some of scoring |
| Cross regulator | Steel | 3 | 3 | | |
| Control gate | Steel | 14 | 12 | 2 | un-balanced opening |
| | Total | **222** | **197** | **5** | |
| **All Infrastructural Effectiveness (%)** | | | | **97.5%** | |

**Appendix table 11. Determination of Water stored (retained) depth in the root zone(Ws)**

**Table 4.6. Determination of Water stored (retained) depth in the root zone(Ws)**

| Location of field | soil depth (cm) | Sampling Time | Average% of Moisture (Wt base) | Moisture Difference (%) | Average BD ($g/cm^3$) | Moisture content (vole ,base) | Root Depth (mm) | stored depth (mm) | Total stored depth (mm) |
|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | | | | | | (2*3) | | (4*5/100) | (sum) |
| **Head** | 0-30 | BI | 37.5 | 7.28 | 1.23 | 8.96 | 300 | 26.8 | **38.03** |
| | | AI | 44.78 | | | | | | |
| | 30-60 | BI | 37.12 | 3 | 1.24 | 3.72 | 300 | 11.2 | |
| | | AI | 40.12 | | | | | | |
| **Middle** | 0-30 | BI | 33.17 | 8.57 | 1.15 | 9.8555 | 300 | 29.57 | **42.11** |
| | | AI | 41.74 | | | | | | |
| | 30-60 | BI | 36.12 | 4.7 | 1.25 | 4.175 | 300 | 12.53 | |
| | | AI | 39.46 | | | | | | |
| **Tail** | 0-30 | BI | 34.16 | 7.29 | 1.15 | 8.3835 | 300 | 25.15 | **36.06** |
| | | AI | 41.45 | | | | | | |
| | 30-60 | BI | 33.22 | 2.91 | 1.25 | 3.6375 | 300 | 10.91 | |
| | | AI | 36.13 | | | | | | |
| **Average** | | | | | | | | | **38.73** |

**Appendix table 12.Average Applied depth of water in (mm)**

| Location of Fields | Area ($m^2$) | Time (s) | Time (Hr) | Depth (mm) | Q (L/s) | Total Volume (Lit)=(5*2) | Total Volume ($m^3$) | Applied Depth (mm)=(7/1) |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| **Head** | 1500 | 14200 | 3.94 | 96 | 7.4 | 105080 | 0.0701 | 70.05 |
| **Middle** | 752 | 9543 | 2.65 | 85 | 6.2 | 59166.6 | 0.0787 | 78.68 |
| **Tile** | 1115 | 11740 | 3.26 | 88 | 6.5 | 76310 | 0.0684 | 68.44 |
| | | | | | | | **Average** | 72.39 |

**Appendix table 13.Farmers Field Application Efficiency (AE) in each plot**

| Location of Field | Average stored Depth (mm)=1*2) | Average Applied Depth(mm) | Average Application Efficiency(%)=(3/4)*100 |
|---|---|---|---|
| **Head** | 38.03 | 70.05 | 54.30 |
| **Middle** | 42.11 | 78.68 | 53.5 |
| **Tile** | 36.06 | 68.44 | 52.69 |
| **Average** | **41.2** | **72.39** | **53.5** |

**Appendix table 14. Average storage Efficiency in each plot**

| Location 0f field | Average BD g/cm3 | Average TAW in % | Average TAW | total Root depth mm | depletion factor | Required depth mm | Stored depth mm | Average storage Efficiency % |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | | | | | (1*3*4*5) | | (7/6)*100 |
| **Head** | 1.245 | 10.505 | 0.105 | 600 | 0.75 | 58.85 | 40.35 | 77.36 |
| **Middle** | 1.245 | 9.31 | 0.093 | 600 | 0.75 | 52.16 | 47.19 | 80.18 |
| **Tile** | 1.245 | 8.105 | 0.081 | 600 | 0.75 | 45.41 | 36.06 | 79.41 |
| **Average** | | | | | | **52.14** | **41.2** | **78.98** |

**Appendix table 15. Characterization of experimental site**

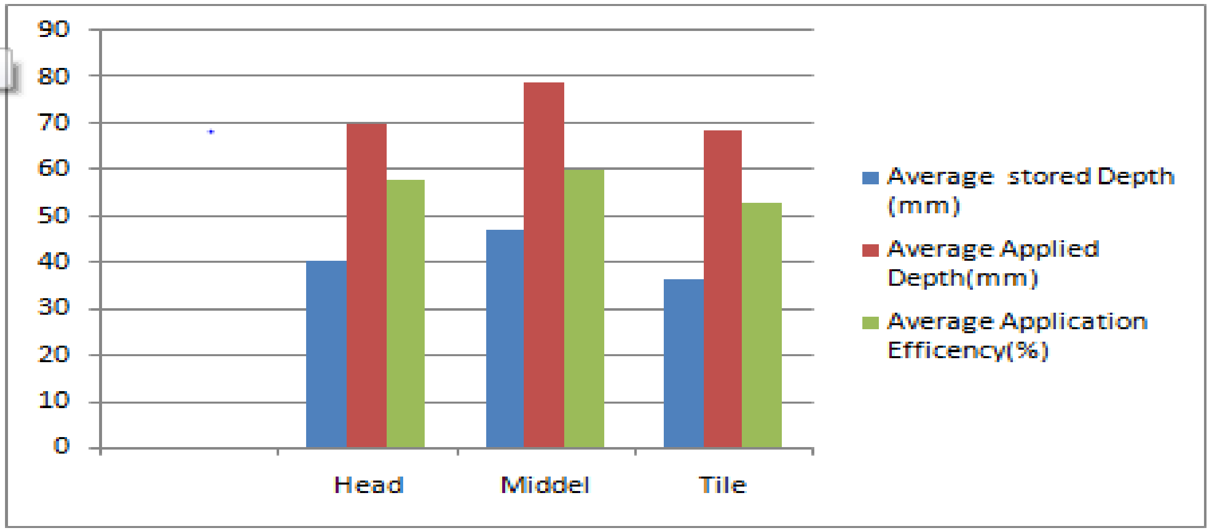
| Types of structures | Bothe lined and earthen canals |
|---|---|
| Source of water | Koga river |
| Reservoir capacity | 18144 M3 |
| Length of Lined secondary canals | 779m |
| Length of Lined tertiary canals | 21000m |
| Length of earthen tertiary canals | 1100m |

| | |
|---|---|
| Year of construction | 2002 E.C |
| Planned irrigable area | 368ha |
| Actual irrigated area | 391ha |
| Total number of Beneficiary | 493Hs |
| Major crop grown | wheet, potatoes, onion |

**Appendix table 16: 10 years average monthly metrological dates (2009-2019)**

| **Station** | | | **Bihar Dar** | | | |
|---|---|---|---|---|---|---|
| **Lat** | | | **11.59** | | | |
| **Long** | | | **37.388** | | | |
| **Elv** | | | **1800** | | | |
| **Month** | **Temperature min** | **Temperature max** | **Wind** | **Rainfall** | **Sunshine** | **Relative Humidity** |
| JAN | 7.8 | 27.5 | 0.7 | 1.2 | 9.5 | 43 |
| FEB | 10.1 | 29.5 | 0.8 | 11.2 | 9.5 | 40 |
| MAR | 12.8 | 30.2 | 1 | 14.3 | 9.1 | 40 |
| APR | 10.3 | 30.6 | 1.1 | 27.9 | 9.2 | 40 |
| MAY | 15.8 | 29.6 | 1 | 94 | 8.1 | 56 |
| JUN | 13.9 | 28.5 | 0.9 | 167.6 | 6.9 | 67 |
| JUL | 14.4 | 24.7 | 0.8 | 413.4 | 4.9 | 76 |
| AGU | 14.3 | 25.2 | 0.7 | 387.3 | 4.8 | 88 |
| SEP | 14 | 26.2 | 0.8 | 195.6 | 6.5 | 74 |
| OCT | 13.8 | 27 | 0.7 | 83.6 | 8.6 | 65 |
| NOB | 11.6 | 27.1 | 0.7 | 26.9 | 9.3 | 58 |
| DEC | 12.6 | 27.8 | 0.8 | 129.4 | 7.9 | 56 |

Appendix graph 17. Application efficiency of each test plot




| Field | Stored Depth(mm) | Applied Depth(mm) | AE (%) |
|---|---|---|---|
| **Head** | 40.35 | 70.05 | 57.60 |
| **Middle** | 47.19 | 78.68 | 59.98 |
| **Tile** | 36.06 | 68.44 | 52.69 |
| **Average** | **41.2** | **72.39** | **56.76** |

# Appendix 2:-Figures

Appendix Figure 1: Soil lab result in Amhara design & supervision work enterprise (Inguti SSI).

Amhara Design & Suppervision Works Entrp
Laboratory Servise
Soil Chemistry & Water Quality Section

አማራ የዲዛይንና ቁጥጥር ስራዎች ድር፤
ላቦራቶሪ አገልግሎት
የአፈር ኬሚስትሪ ና ውሃ ጥራት ክፍ

**Soil Analysis of Laboratory Report**
Client : Wubliker Negese

| Sr. No. | Lab. No. | Client Code | Client depth (cm) | pH ($H_2O$) | Texture % Sand | Texture %Silt | Texture % Clay | Texture Classes | FC % | PWP % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inguti SSIS | | | | | | |
| 1 | 1065/20 | WNL | 0-30 | 4.72 | 13 | 25 | 62 | Heavy Clay | 25.14 | 17.29 |
| 2 | 1066/20 | WNL | 30-60 | 4.89 | 11 | 15 | 74 | Heavy Clay | 24.95 | 16.59 |
| 3 | 1067/20 | WNM | 0-30 | 4.71 | 17 | 21 | 63 | Heavy Clay | 27.35 | 18.05 |
| 4 | 1068/20 | WNM | 30-60 | 4.84 | 9 | 25 | 66 | Heavy Clay | 27.23 | 17.91 |
| 5 | 1069/20 | WNU | 0-30 | 4.76 | 9 | 15 | 76 | Heavy Clay | 26.88 | 16.79 |
| 6 | 1070/20 | WNU | 30-60 | 4.98 | 17 | 19 | 64 | Heavy Clay | 26.75 | 16.64 |
| | | | | | Gota SSIS | | | | | |
| 7 | 1071/20 | Be-M | 0-30 | 5.56 | 25 | 19 | 56 | Clay | 31.49 | 17.38 |
| 8 | 1072/20 | Be-M | 30-60 | 5.72 | 23 | 17 | 60 | Clay | 31.31 | 16.98 |
| 9 | 1073/20 | Be-D/S | 0-30 | 5.67 | 31 | 25 | 44 | Clay | 32.25 | 18.15 |
| 10 | 1074/20 | Be-D/S | 30-60 | 5.71 | 17 | 23 | 60 | Clay | 32.09 | 18.02 |
| 11 | 1075/20 | Be-U- | 0-30 | 5.48 | 23 | 21 | 56 | Clay | 31.78 | 16.84 |
| 12 | 1076/20 | Be-U- | 30-60 | 5.57 | 25 | 21 | 54 | Clay | 31.54 | 16.71 |
| | | | | | Dirma SSIS | | | | | |
| 13 | 1077/20 | ES-M | 0-30 | 5.65 | 39 | 33 | 28 | Clay Loam | 28.35 | 14.99 |
| 14 | 1078/20 | ES-M | 60-90 | 5.68 | 40 | 33 | 27 | Clay Loam | 28.24 | 14.92 |
| 15 | 1079/20 | ES-T | 0-30 | 5.28 | 55 | 29 | 16 | Sandy Loam | 18.23 | 9.46 |
| 16 | 1080/20 | ES-T | 60-90 | 5.34 | 53 | 27 | 20 | Sandy Loam | 17.89 | 9.25 |
| 17 | 1081/20 | ES-H- | 0-30 | 5.48 | 21 | 31 | 48 | Clay | 31.87 | 19.24 |
| 18 | 1082/20 | ES-H- | 60-90 | 5.54 | 33 | 26 | 41 | Clay | 31.65 | 19.08 |

Name Of Chemist Abel Ayele Checked by ____ Approved by ____
Date 09/11/2012 Date 9/11/2012 Date 9/11/2012
Sign ____ Sign ____ Sign ____

Appendix Figure 2: Field water application depth and discharge measurement with RBC flume.

Appendix figure 3.Poor canal maintenance

Appendix figure 4.Irrigation command areas

Figure 3.6: Photo of irrigation command areas

Appendix figure.5. Infrastructures at irrigation unite

Figure, 3.5: Tertiary earthen canals(TEC), Tertiary lined canals(TLC) secondary canals (SC)

Appendix 3:- Questioners Prepared For Beneficiaries/Farmers

## I. Personal Data/Household data characteristics

Region___________ Zone ___________Woreda ______ Scheme name _______ Bloke _________

location of plot________________ Date___________

1. Who is the head of household? A. Husband B. Waif C. Bothe
2. Sex composition of the household. A. Male B. Female
3. Age composition of the household. A. <18yrs B.18-45yrs C. >45yrs
4. Marital status of the respondent A. Married B. Widowed C. Divorced D. Unmarried
5. Education level of respondent. A. Illiterate B. High school complete C. Read and write only D. Diploma and above E. Elementary
6. Household irrigation land size A. <0.5 ha B. 0.5-1.5ha C. >1.5ha

## II. Beneficiary farmers' Questionnaire to conflict related problems.

1. Have you ever come across a conflict between those living around the canal tertiary units and the downstream users? A. Yes B. No
2. If you "Yes" question number 1, what are the main cases of the conflict?
   A. Unequal water distribution/Mgt B Scarcity of water C. Poor irrigation scheduling
   D. Water theft E. Land shortage
3. How often conflicts among water users happened?
   A. Most of the times B. Some times C. Rarely
4. Who is the actor of resolving the conflicts among water users?
   A. Keble councilor B. Water committee C. The village people D. Others__________
5. Who manages and control the irrigation water?
   A. The community as a whole B. Representatives of the community C. Keble or PA administrators D. Others________________________
6. Do you see any conflict on water use in the further? A. Yes B. No
7. If yes question number 6, what will be the causes? _________________________________
8. What should be done to avoid the conflict? ________________________________________

### III. Questions related to canal maintenances and its performances

1. What are the major causes for the failure of canals and other irrigation infrastructures? A. Cart and lorry road B. Livestock C. Livestock and cart E. others________
2. What factor influence for poor maintenance of irrigation infrastructures? A. Poor working integrity/organization B. Insufficient finical support C. poor performance of WUA E. others___________________________
3. Is the quantity of water distributed matches with the required amount? A. Yes B. No
4. If No question number 3, what are the reasons? A. Improper planning B. Leakage & loss in the structure, C. Siltation problem in the canal
5. Is the water distribution is adequate? Yes_____________ No _____________
6. If no question number 5, what will be the causes of inadequate distribution? A. Seepage and loss in the structure B. Debris and algae C. sedimentation and weeds others ___________________
7. What factor influence performances of irrigation infrastructures?

A. Sedimentation of canal B. Canal seepage C. Infrastructural damage/loss Others_______

### IV. Questioners related to Farm water managements evaluations and irrigation practices

**1.** How many hectares of your cultivated land are accessible for irrigation? __________

**2.** Do you irrigate all of your irrigable land? A. Yes B. No

**3.** If you no question number 2, why? A. Shortage of water B. Low productivity C. Getting sufficient produces by rain feed agriculture D. Poor quality of irrigation E. poor maintenance F. Others _____________

**4.** Are there special considerations for crop type and stage of growth during water allocation for irrigating to crop? A. Yes B. No

**5.** What are the major agricultural crops you produce using irrigation? _____________

**6.** Why do you prefer to grow such crops? A. Better price B. Good production C. Easy to operate D. High disease tolerance E. Seeds availability F. Others __________________

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

A. No, water is provided as a free service

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

C. Irrigation water charge is based on the volume of water used

D. Others _______________________________________

8. Who decides irrigation scheduling? (When and how much) to irrigate?

A. Water User Association B. Scheme Beneficiary /users C. Development Agent D. Keble Administration E. Irrigation Committee

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

A. Wait until see signs of wilting on the leaves B. Check the soil near the roots

C. When it is dry, I irrigate D. Irrigate every day E. Others ________________________

10. Is there any problem during the application of irrigation water? A. Yes B. No

11. If you yes question number 9, what are they? And Rank them______________________

A. Downstream conflict B. Shorter time allowed for irrigation water flow

C. Water use administration problem D. Lack of maintenance

E. Lack of operational skill/training F. Others_____________

12. Are you able to apply as much water as you would like to your crops? A. Yes B. No

13. What challenges affect you in using the scheme efficiently? ( ordering theme)

A. Lack of input financing B. Unavailability of inputs

C. Shortage of labor D. Lack of rural access road & high transportation cost

E. Conflict in water utilization with users F. Lack of marketing for produce

G. Water shortage H. Others_______

**IIV. Questionnaires related to Institutional support and organizations for sustainability of irrigation scheme.**

**1.** Is there nearby government/private owned small scale irrigation? A. Yes B. No

**2.** If yes, do you have any relation with them? A. Yes B. No

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

A. Field day or demonstration B. On-farm verification

C. Market facilitation D. Input provision E. Others (specify) ____

**4.** What kind of institutional support do you need in relation to the scheme? A. Organization and management B. The schemes capacity C. Maintenance D. Others ____

**5.** Do you have any specialized training on irrigation? A. Yes B. No

**6.** Do the schemes have been constructed with the consent and full participation of the target beneficiaries? A. Yes B. No

**7.** If you yes question number 6, in what aspect did you participate?

A. Simply attending discussion assemblies about the project

B. Attending discussion assemblies and actively expressing feelings, ideas, and views.

C. Acting as an inform D. Others____________________

**8.** Have you ever participated in maintenance of the irrigation scheme? A. Yes B. No

**9.** If you do not make the maintenance, what is the reason do not make maintenances of scheme? A. It is not my responsibility B. I do not know how to do it

C. If there is others specify it______________________

**10.** What do you feel/think the performance of WUA Committee in scheme managements? A. Very Good B. Good C. Medium D. poor

11. Did you get extension services and trainings from NGOS/Go's A. Yes B. No

12. If you yes question number 11,what supporting services to get from GOs/NGos

A. Technical support/advice B. Input supply for irrigation C. Maintenances

D. Infrastructural support E. Others_________________________________

13. what factors that influencing the success of WUA in relation to scheme irrigation managements A. Lack of cooperation/integrity B. Transparency and accountability C. Low income D. workload