EVALUATION OF THE PERFORMANCE OF TRADITIONAL IRRIGATION SYSTEM IN DEGALUNA TIJO WOREDA, ARSI ZONE, OROMIA REGION

HAWASSA UNIVERSITY

INSTITUTE OF TECHNOLOGY, FACULTY OF CIVIL ENGINEERING AND BUILD ENVIRONMENT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR DEGREE OF MASTER OF SCIENCE IN HYDRAULIC ENGINEERING

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November, 2018

HAWASSA, ETHIOPIA

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ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled **"EVALUATION OF THE PERFORMANCE OF TRADITIONAL IRRIGATION SYSTEM IN DEGALUNA TIJO WOREDA"** submitted in partial fulfillment of the requirements for the Degree of Master's of Science with Specialization in Hydraulics Engineering, the Graduate Program of the Department/ Faculty civil Engineering and Build Environment, and has been carried out by Seyoum Tadesse ID. No PGHY/093/06, under my/our supervision. Therefore I/we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by Seyoum Tadesse have read and evaluated his/her thesis entitled **"Evaluation of The Performance of Traditional Irrigation System In Degaluna Tijo Wareda"**, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department /School Graduate Committee (DGC/SGC) of the candidate's department.

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Biographical sketch

The author was born in Oromia Regional State in Arsi Zone, Digaluna Tijo District, and Sagura Town on February 12, 1988. He attended his elementary school at Limat Behebret and Assela Melestegna and Assela junior school at Assela Junior Secondary school. He then continued his high school education at Assela Comprehensive High school in Asella town where he completed in 2007 G.C. After completing high school, he joined the Hawassa University, Technology Institute in November 2008 G.C, and completed his study on July, 2013 G.C academic year, graduated with BSc degree in Irrigation and water resource Engineering.

In February 2014, he joined the Graduate School of the Hawassa University as a candidate for Master of Science degree in Hydraulic Engineering (School of Civil Engineering).

List of Acronyms

AESE	Agricultural Economics Society of Ethiopia
AMS	Available Moisture Storage
ASMD	Available Soil Moisture Depletion
CSA	Central Statics Agency
CUC	Christiansen Uniformity Coefficient
CWP	Crop Water Productivity
D/S	Down Stream
Da	Applied Depth
Dmin	Minimum infiltrated depth
DPR	Deep percolation ratio
Du	Distribution Uniformity
Ea	Application Efficiency
Ec	Conveyance Efficiency
EFSS	Ethiopian Food Security Strategy
Es	Storage Efficiency
ET	Evapotranspiration
ETc	Crop evapotranspiration
ETo	Reference Evapotranspiration
EWP	Economic Water Productivity
FAO	Food and Agriculture Organization
FC	Field Capacity
IFAD	International Finance Aid Development
IWMI	International Water Management Institute

M/S	Middle Stream
MoA	Mister of Agriculture
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
MoWIE	Minster of Water, Irrigation, and Energy
MoWR	Ministry of Water Resources
NGO	Non-Governmental Organization
PWP	Permanent wilting point
RAW	Readily available water
RIS	Relative Irrigation Supply
RS	Remote Sensing
RWS	Relative Water Supply
SMD	Soil Moisture Depilation
TAW	Total Available Water
TFC	Total Field Capacity
TPWP	Total Permanent Wilting point
U/S	Upper Stream
UNCED	United State Center of Economic Development
USDA	United State Department of Agriculture
WUA	Water User Association
WUC	Water User Community
WUG	Water User Group
WAP	Water Association Peasant

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Abstract

This study was carried out at Degaluna Tijo Woreda traditional irrigation scheme with the objectives of characterization of the scheme, evaluating the performance of scheme using selected performance efficiency indicators and analyzing water productivity in relations to water applied. In the highlands of Ethiopia, irrigation practices have long been in use since ancient times for producing food crops. It was low momentum irrigation development, whereas the developed irrigable land had not been irrigating as expected. The areas that had been to use accounts less than 20% of the total irrigable land. It was made by measuring canals capacity and efficiency, length of water flow. Performance evaluation of the scheme was made using selected performance indicators such as conveyance, application, storage efficiencies, and distribution uniformity along with the water productivity in terms of water use efficiency as well as external indicators. The result obtained showed that conveyance efficiency of 82.69%, 75.27 %, and 80.45%, respectively. In the field that application efficiency, storage efficiency and irrigation efficiency on economic eight farmers' plot located on different ends of the command 49-58%, 42-60 % and 57-89% upper, middle and downstream irrigation scheme respectively. Regarding the output per area, Temela Gusha was better than other systems, but for the output per water supply the converse was true that is, Hobori was better than others were. The institutional arrangement was poorly to support the irrigation farm association and crop pattern trends with the crop water consumption. It observes that from time trend of remote sensing image environmental climate condition famine change rapidly accelerated from time to time.

Keywords: Irrigation performance, internal and external indicators, water productivity, and conveyance efficiency.

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Irrigation is the processes of water application into the ground to support the crop water requirement for increasing the crop production and satisfies the economic development of the country. An overpowering proportion of early agriculture took place along the river banks, deltas, and floodplains, where as abundance of water for agriculture. Not with standing that, these may not be strictly defined as irrigation, as they were dependent on non-rainfall sources for agriculture. Human beings to start using engineering skills to block rivers, create reservoirs and channels, and divert water to areas of interest to sustain their food needs. Since, great civilizations flourished along the great rivers; With time and increases in populations, humans started using engineering skills to block rivers to divert water (Johnston 1886).

Ethiopian economy has accountable about 85% of total economy depending upon the periodic rain-fed agriculture production with limited use of irrigation for agricultural production. Since, 75% of fresh water in worldwide has being consumed by irrigated agriculture, more efficient, effective and sustainable use would be more important and it would help to cope with water scarcity in other sectors (Selin, et al., 2008). Irrigation is critical to food security and economic growth in a country. Agriculture is the backbone of the country economy but it depends on seasonal rainfall and some traditional irrigation only. Water is one of the fundamental basic components for all living things in the world. According to studies of Belete (2006), it estimated that more than 90% of the food supply in the country comes from low productivity rain-fed farmers. The major problem associated with the rainfall-dependent agriculture in the country is the high degree of rainfall variability and unreliability. FAO (1994) irrigation paper reports justify that, the next two decades, water have been expected as the most important factor for the conversion of low productive rain-fed agriculture into most effective and efficient irrigated agriculture. Ethiopia has an estimated irrigation potential of about 3.5 million hectares (Awulachew et al.., 2007b).

Based on the size of the command area, irrigation schemes in Ethiopia is classified in small scale (<200 hectares ha), medium scale (200-3,000 ha) and large scale (>3,000 ha) irrigation systems (MoWR, 2002). Small-scale irrigation schemes are further classified in to modern schemes and traditional schemes. Modern schemes usually have fixed or improved water control or diversion structures. On the other hand, traditional irrigation schemes are different from the modern schemes because their diversion materials are usually made from local materials, and are usually reconstructed every year per season (Werfring, 2004). Traditional irrigation scheme was one of the initial bases of civilization for the world as well our country. The suitability of the land use can be evaluated for identification of the total cultivated land verses currently on the progress of farming system. Moreover, the amount of flow in river catchments with limited stream flow data can be determined from runoff coefficient of gauged river basin, to check matching of water supplies and water demand or requirement (FAO, 1993; FAO, 1997).

According to Saymen (2006), surface irrigation offers a number benefits for the less skilled and low level farmers. Irrigation water supplies and their requirements are therefore, important physical factors in matching the available supply to the requirements. In traditional practices, appear to have wide spread in the pre-colonial period and some have persisted to the present day. Irrigation was often conventionally defined as simply by the fact that the particular concern of experts from the discipline of engineering is employed in its planning, design and management. In fact, any study or irrigation in Africa, which is not to deliberately blind to traditional scheme practices and the history of past development, initiative must adopt a specific definition, and one, which is broad in scope.

In Ethiopia Sulas et al. (2009) in the study conducted to investigate whether irrigation was a key factor in state formation and urban development in the ancient civilization of Axum, Northern Ethiopia, found insufficient information apart from water managements of rain fed agriculture. However, in Ethiopia, traditional irrigation was practiced before centuries (Bekele et al., 2012). Moreover, in the highlands of Ethiopia, irrigation practices have long been in use since ancient times for producing food crops (Awulachew et al., 2007; Bacha et al., 2011; MoA, 2011b). Different authors such as Awlachew et al. (2007), Makombe et al. (2007), and Hagos et al. (2009) stressed that smallholder farmers of Ethiopia have practiced supplementary irrigation for centuries to solve their livelihood challenges. So the modern technology, educational design and by supporting method of irrigation practice is the gradual development of the ancient civilization of irrigation method was the current key for well design of engineering irrigation design.

1.2. Irrigation development in Oromia Region

According to OIDA, 1999, Oromia irrigation potential study has 63 river systems and 688 tributary streams which annually generate 58 billion cubic meters of surface water, the equivalent of half the nation's surface water resources. Despite the large water resources potential, Oromia's agricultural sector is almost entirely dependent on rain fed farming. Irrigated agriculture constitutes just fewer than 5 percent of the potential and about 2.14 percent of the total cultivated land. The implication of this figure is that irrigated agriculture has to go a long way before it can make a significant contribution towards regional food security. In Oromia Region, it stated that out of the estimated 1.7 million ha of potential irrigable land, only 85,400 ha have developed so far, which about 5% of the potential is the modern irrigation practice in many places has introduced as late as mid 1980's when there was a countrywide drought affecting huge number of population. In 1998, about 92,617ha of land were under traditional irrigation. These schemes were estimated to cover 48,816ha, constitute the major portion, followed by large-scale state farms consisting of 26,506ha. Finally, the total developed and planned area, for the development of irrigated agriculture is estimated at 583,998ha.

1.3. Statement of problem

As indicated by different sources, Ethiopia was started to begin irrigation practice before a century, but until now, the irrigation practice is not well used in terms of water resource and capacity of land to be cultivated. While for the last two or three decad, millions of Ethiopian households have suffered from continuing depression characterized by recurrent droughts that led to shortage of food as a result of luck of enough rainfall which affect the production and food insecurity (Webb et al., 1994). Furthermore, the country could not meet its large food deficits through relying on rain-fed agricultural production alone. Agricultural production in Ethiopia is primarily rain fed, so it depends on erratic and often insufficient rainfall. As a result, there are frequent failures of agricultural production. Irrigation has the potential to stabilize these failures of agricultural production and mitigate the negative impacts of variable or insufficient rainfall. Various authors confirm that irrigation increases agricultural productivity and farm income per ha (Hussain 2006; Nhundu et al., 2010; and Gebremedhin, 2015).

According to Mekonen the irrigation development plan of Ethiopia, 274,612 ha of land have been developed until the year 2016. From total current cultivable land, 147,474 ha are under larger and medium scale project and 127,138 ha under small-scale projects (Mekonen, 2005). They employ traditional methods and their intake structures are often temporary, having to be replacing from time to time. Most of the water that was diverted is lost due to earthen canal by seepage and mouse boring around canal before reaching the field and efficiency in the field is very low. Degaluna Tijo Woreda has low momentum of irrigation development, whereas the developed irrigable land had not been irrigating as expected. The areas that had been to use accounts less than 20% of the total irrigable land. In addition, the investment in small-scale irrigation promotion can be justified from the standpoint of effective and reasonable use of the developed irrigation land and water resources. The development of water resources for agricultural purposes (irrigation) is rising rapidly.

The traditional irrigation schemes in Degaluna Tijo Woreda have exposed to water shortage problems in controlling flood water; sediment transported and earthen embankment canal damage. The main reason no permanent diversion structures and flexibility during high rainfall period, so, traditional diversion w include work local materials like stone, boulders, shrubs, and logs of trees. These structures are mostly temporal and can be eroded when large floods occur and as a result, most of the sediments will be easily transported this sediment clogged canals due and damage canals and head work local material failures. Before twenty years ago, the number of tradition irrigation schemes were above one hundred eighty, but currently the number reduced due to the expansion of small-scale irrigation and their collapse as result of some river become approach to dry. The reduction of existing number of traditional irrigation is also depending on population growth.

For general objective of this study is to identify the performance irrigation scheme, factors that affect the scheme and institutional support on traditional irrigation scheme in Oromia Region; Arsi Zone, taking the case of eight irrigation schemes from Degaluna Tijo Woreda with the objective of:-

- ❖ To evaluate the performance of the traditional irrigation schemes;
- ❖ To assess institutional support service and problems prevailing the schemes; and;
- ❖ To examine factors affecting the traditional irrigation schemes.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Definition of irrigation

Water is the largest resource of all living things. It is not only assist in survival but also helps in making life comfortable and luxurious. Besides various other way of water, the largest use of water in the world is making for irrigating lands. Irrigation, in fact, is nothing but “a continues and relabeled water supply to different crops in accordance with their different needs”. Irrigation is the science of artificial application of water to land, in accordance with the crop requirement throughout the crop period for full flied nourishment of the crops (Garg 2015). Irrigation is a means of good farming husbandry, better land utilization, and stable and higher crop production. Sustained growth and strength in agriculture is a fundamental necessity to meet the increasing demand for food and other products relative to population growth. Irrigated agriculture will play a major role to reach the broader development vision of the country in achieving food security, poverty alleviation, and improvement in the quality of life. The main importance of irrigated agriculture is to provide plants with enough water to prevent stress that may cause reduced yields or poor quality of harvest (Haise and Hagan, 1987). Irrigation has contributed significantly to poverty reduction, food security, and improving the quality of life for rural population. The majority of existing traditional and modern irrigation schemes is often community-based and traditional methods, covering less than 200 hectares (Seleshi *et al.,* 2010).

Irrigation is critical source to release food security and economic growth in a country. Agriculture is the backbone of the country economy but it depends on seasonal rainfall and some traditional irrigational only. According to Belete (2006) studies, it estimated that more than 90% of the food supply in the country comes from low productivity rain fed smallholder. Ethiopia is one of the few African countries light with relatively abundant water resources, favorable climate, and potentially huge irrigable land, while the potential benefits of irrigation are great and the actual achievement in many irrigated areas of the country is significantly less than the potential. According to MoWR (2005), Ethiopia is estimated to have 3.7 million ha of potentially irrigable area with the available surface water resources and the land irrigated through the development of traditional and modern irrigation schemes are estimated to be about 386,603 hectares, which is about 10 per cent of potentially irrigable land.

2.2. Importance of irrigation in Ethiopia

Of all sectors of the economy, agriculture is the most sensitive to water scarcity. Currently, agriculture accounts for 70 percent of global freshwater withdrawals, and more than 90 percent of its consumptive use. Under acceleration of population growth and changes in relating to diet habits, food consumption is increasing in most regions of the world. It expected that by 2050 an additional billion tons of cereals and 200 million tons of concentrate have needed to produce annually to satisfy global growth of food demand (FAO, 2012). Considering this major distribute of the world`s water resource is used in agriculture and food requirements are increasing while global water resources are limiting irrigated agriculture. Therefore, the roles of efficient irrigation systems and techniques have recently assumed greater importance for increasing food production. As FAO (2012) pointed out that, over the past 30 years, the world's total agricultural production has doubled, while the expansion of cultivated land was only about 15 percent and all of this growth was occurred in land equipped for irrigation.

In worldwide, there is still unpredicted potential for use of land and water resources for agriculture. The globally positive situation should not hide the fact that in large areas of the developing country, agriculture is facing its limits, either by lack of water or lack of land. It is predicted that by 2025, most developing countries will face either physical or economic water scarcity, while at the same time global demand for food will increase (Molden, 2007). Because of irrigated and rain fed agriculture is by far the largest consumptive use of fresh water, improving the productivity of water in agriculture can assist the incremental food production while continuing water related environmental services.

2.3. Irrigation potential in Ethiopia

Ethiopia has an estimated irrigation potential of 3.5 million hectares (Awulachew et al. 2007b). During the year 2005/2006 the total estimated area of irrigated agriculture in the country was 625,819 ha, which, the total, constitutes about 18% of the potential (MoWR 2006). It is planned to expand irrigation development in the country by an additional 528,686 ha in the year of 2010 (Atnafu 2007MoFED 2006), which will constitute about 33% of the potential. Among the year 2025, 83% of the expected global population of 8.5 billion is expected to be live in developing countries. The role of water as a social, economic, and life-sustaining good should be reflected in demand management mechanisms and be implemented through resource assessment, water conservation and recycle (UNCED, 2002). The challenge for today's irrigated agriculture is to contribute to the world's food production and to improve food security through more efficient and effective use of water.

Irrigation is any process other than natural precipitation, which supplies water into crops, orchards, grass, or any other cultivated plants (Stern, 1989). Traditional irrigation practices therefore, refers to the irrigation practices, which have involved over the cause of time, without any known outside institutional intervention.

Table 2.1 The potential area and actual status of small-scale irrigation in Ethiopia

Reference Source	Potential irrigable area (ha)	Actual irrigated area (ha)		Notes/observations
CSA (1998)	-----	95/96 84,640	96/97 68,210	Maher (main rainy) season
AQUASTAT (1998)	165,000 - 400,000	63,581		An online database supported by FAO. Rises issue of need for rehabilitation
MWR (1998)	180,000	64,000		Notes that some schemes are not functioning and in need of rehabilitation
Tahal (1998)	---	40,270		Traditional Schemes only those without assistance from outside the community
IDD/MOA (1993)	352,000	70,000		Estimate of traditional irrigation without external assistance

Source: Programmatic Environmental Assessment of small-scale irrigation in Ethiopia, 1999.

These practices are the results of gradual learning processes and emerge from a knowledge base accumulated by rural people through long processes of observing, experimentation, and processes of fail through generations' people's experience and understanding. Traditional irrigation practices are also shaped and emerge from detailed understanding of local conditions and are modified in response to changing socio economic, political and ecological conditions (Hans *et al*, 1996). According to the Ministry of Agriculture MoA (1992) there are about 933,000 ha of land potential for irrigation from surface water resource including underground water, out of which about 144,000 ha are under partial or full scale irrigation of which traditional small scale irrigation systems account for 120,378 ha while 23,622 ha are under large scale estate farms.

2.4. Traditional irrigation scheme

In Ethiopia, traditional irrigation was practiced before centuries (Bekele *et al*., 2012). Moreover, in the highlands of Ethiopia, irrigation practices have long been in use since ancient period producing for subsistence food crops **(**Awulachew *et al.*, 2007; Bacha *et al*., 2011; MoA, 2011a). Studies of Awlachew et al., (2007); Makombe et al., (2007); Hagos et al., (2009) stated that supplementary irrigation has been practiced by smallholder farmers of Ethiopia for centuries to solve their livelihood challenges. The irrigation area in the year 2002 was 197,000 hectares with a coverage distribution of 38 percent traditional, 20 percent modern communal, 4 percent modern private and 38 percent public schemes (MoWR 2002). The revised figure puts the total irrigated area at about 250,000 ha (Awulachew *et al*. 2005).

Traditional methods of irrigation involves different ways by obtaining water from wells, Lake, and canals and delivered it to field with the help of cattle or human labor. To understand how irrigation works and its importance, we discus about small-scale irrigation and originate some normally known traditional irrigation methods and their significance. Irrigation is a way for farmers to manipulate existing water sources to either store or distribute the resource. Irrigation strategies are necessary to all forms of agriculture due to the irregularity of the weather. It provides a guarantee that there will be water in the case of a drought. It also has the added benefit of keeping the plants at a normal temperature level to mitigate frost during cold spells and stops them since temperature increase. Irrigation is also necessary to promote evaporative cooling and come into grow formation of some microorganisms are helped with the added moisture (Jamal and Shinwari, 2013).

2.5. Properties of performance indicators

The performance assessment in irrigation schemes is possible through use of comparative indicators. Those indicators are external and internal indicators. External indicators are based on outputs and inputs from and to an irrigated agricultural system (Molden et al., 1998). Internal indicators on the other hand relate performance to internal management targets. Internal irrigation performance is related to farmers' level of satisfaction by some authors (Ghosh et al., 2005). Unlike internal indicators, external indicators inform the important and outputs of irrigation with respect to the inputs and are practically fewer informative as to what internal processes resulted in the outputs. It is very conceptual that external indicators relation with outputs to inputs, there are indicators for comparative purposes. Those comparative performance indicators were used for study to assess and compare the performance of the Woreda’s community method of irrigation schemes managing. These are water supply, agricultural output, and physical sustainability indicators. Efficient water managing was one of the key elements in successful operation of irrigation schemes. The Classical short falls of irrigation schemes comprise among others:

- ❖ Irregular water distribution at the different grading levels throughout the irrigation network,
- ❖ Disparity between water supply and crop water requirement,
- ❖ Uncontrolled seepage losses from the canal conveyance network,
- ❖ Disparities between heads and tails along water courses,
- ❖ Insufficient drainage capacity to dispose excess soil moisture, and
- ❖ The framework of irrigation efficiency and performance assessment has been distilled to quantify the functioning of an irrigation scheme.

The performance indicator includes both an actual value and an intended value that enables the assessment of the amount of variation. It further should contain information that allows the manager to determine, if the normality is acceptable. Some of the necessary attributes of performance indicators suggested by Bos (1997) are-

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

The indicators must be quantifiable*:* the data needed to quantify the indicator must be available, accessible, or measurable with available technology.

Reference to a target value*:* this is obvious to from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator. These target values and their margin of deviation should be related to the level of technology and management (Bos et al, 1991).

2.6. Purposes of comparative performance indicators

The purpose of such study, suggested by Molden *et al* (1998), is to present and apply a set of external and other comparative performance indicators that will allow for comparative analysis of irrigation performance across irrigation scheme. The indicators disclose general notions about the relative wellbeing of the irrigation scheme, however they are not too facts intensive to discourage widespread and regular application. Such a set of indicators potentially has several purposes. The indicators will allow for comparison between existing and earlier period of scheme performance, between different irrigation scheme and water application management, and for different environments, and to assess over time of the trend in performance of a specific project. International water management institute's minimum set of external indicators was originally presented by Perry (1996). The indicators have been widely field-tested and slightly amended. The intention of presenting this set of indicators was to allow for cross-system performance. Some of the features of the indicators are the following (Molden *et al*., 1998):-

- ❖ The indicators are based on a relative comparison of absolute values, rather than being referenced to standards or targets.
- ❖ The indicators relate to the phenomena that are common to irrigation scheme and irrigated agriculture.
- ❖ The set of indicators was small, yet discloses sufficient information about the output of the system.
- ❖ Data collection procedures are not too complicated or expensive.
- ❖ The indicators relate to outputs and are bulk measures of irrigation and agricultural systems, and thus provide limited information about internal processes.

This set of indicators is designed to show gross relationships and trends and should be useful in indicating whereas study that is detailed should take place. This approach differs from that of using ratios of actual to target in that the interpretation of these ratios relative to performance is not always clear (e.g, if the target value is one, is 0.9 better than 1.1). A relative comparison of values at least allows us to examine how well one scheme is performing in relation to others. The main target for these external indicators comprises policy makers and managers making long term and strategic decisions, and during the study who are searching for relative differences between irrigation scheme while the main target for internal indicators comprises irrigation scheme managers interested for day to day operations where ratios of actual to target values may be quite meaningful.

The performance assessment of traditional irrigation scheme is a systematic observation of documentation and understanding of the management of an irrigation scheme, with the purpose of continuous improvement (Bos et al., 2005. Leslie and Sevendsen (1990) stated that, most of the traditional irrigation schemes in developing countries have been performing far below their potential.. International Water Management Institute has opportunity to minimum set of indicators for comparative performance studies in irrigation scheme. Recent studies have attempted to standardize these indicators to allow for better comparison across the scheme systems (Bos et al., 1994). According to Cornish (2005), the selection of indicators for cross comparison has evolved over time and remains runny, as the users get the experience with collection analysis, and diagnosis of the data.

2.7. Institutional arrangement

Institutional and policy reforms in irrigation scheme should not be observed in separation from other reforms taking place in an economy. As poor institutional reform in irrigation may not be effective if only insignificant operational rules are reformed. It may require a much larger scale institutional unexpected overcome such as reforming irrigation governance through public, private, cooperative involvement and there by empowering poor farmers who lack resources. The ultimate purpose of institutional arrangement for performance assessment is to achieve efficient and effective irrigation performance by providing related feedback to management at all levels. The performance assessment concept is essential to successful management of an irrigation scheme. As such, it may assist management or policy makers in determining whether performance is satisfactory or which corrective actions need to be taken in order to preparation the situation. According to Bos et al. (2005), the performance assessment of irrigation scheme can be broadly categorized as:

- ❖ Accountability assessment provides information to assess the performance of those responsible for the system's performance.
- ❖ Intervention assessment is undertaken to determine how to improve some aspects of the scheme's performance.
- ❖ Sustainability assessment enables planners to assess the long-term viability of a scheme.

Indicators are the ways of measuring progress towards the achievement of the goal. They provide an objective basis to track the progress and assessment of final achievements. A good indicator should define the level of achievement, specifically: how much? (FAO, 2002). It is known that some forms of farmers' organization at the scheme level are essential for the smooth operation of the scheme itself. At present, water committees are established at each scheme. The task of organizing irrigators into Water Users Association (WUA) is the accountability of Service Cooperative. Therefore, beneficiary farmers should be organized in to a form of legally recognized and registered Water Users Association in order to be the proper owner of the schemes. According to the information from the department so far, only three irrigation associations have been established and registered in Degaluna Tijo Woredas of the Zone.

2.8. Factor affecting the performance schemes

According to the MoA (2011a), the main factor and opportunities for the development of irrigation in Ethiopia is described below. These narrations provided for explanations of small-scale irrigation schemes. These factors can be explained as technical constraints and knowledge gaps are identified;-

- ❖ Insufficient awareness of irrigation water management and scheduling techniques, water saving irrigation technologies,
- ❖ Inadequate knowledge on improved and diversified irrigation agronomic practices,
- ❖ Scheme based approach relatively than area based approach for the development of irrigation Schemes,
- ❖ Be deficient in of experience in construction and quality of material irrigation projects,
- ❖ Short productivity of existing irrigation schemes,

There is no quantitative index system for irrigation water-use efficiency applicable to Ethiopia. One of the reasons for this is the contents of the terms for different irrigation water efficiency indicators are indistinguishable; resulting in the outcome that many indicators have mixed under different conditions. A second reason is that while the theoretical framework is relatively clear for some indicators, many calculated elements are difficult or impossible to determine in practical applications. This method based on input output is the main way to evaluate efficiency of irrigation water use in the long term, but the input output situations of irrigation actions are dependent upon region and time of water application.

The main problems that can be found in an irrigation canal network include:

- ❖ Limited amounts of water available at the water source;
- ❖ High water consumption in fields close to the water source resulting in water shortages at the tail end of the scheme;
- ❖ Illegal manipulation of canals and materials;

- ❖ Siltation: - plant growth, water losses, and low water levels due to canal erosion.

A canal may be too small to supply enough water to irrigate the area served by the canal, and if the discharge needed is supplied to such a canal, it will be excessive and water will over top. In addition, the water level in a canal may have been imperfectly determined, and if it is, too low water may not enter the fields by gravity. Canal slopes which are too steep may experience erosion from high flow velocities.

Economic factor affecting productivity

In Mozambique, the low agricultural productivity has been seen as a result of lack of appropriate technologies combined with deficient financial supports for agricultural activities. In addition, agricultural markets are commonly distant, unpredictable and not competitive for smallholder farmers. The harmful effect of the current irrigation techniques to the environment include, soil decline, reduction and pollution of water sources, wasteful energy use, decrease of biodiversity, and degradation of non-agricultural habitat (FAO, 2004).

2.9. Productive of irrigation scheme

Irrigation development aims to bring about increased irrigation production and consequently to improve the economic and social wellbeing of the rural population. Properly implemented smallholder irrigation with right technologies may have a considerable potential improving rural livelihoods, although the viability of such systems becomes questionable when the financial responsibility rests entirely on the community in the absence of institutional support services that enhance market orientation (Kamara et al. 2002). The issue of smallholder irrigation expansion should focus on institutional linkages, access to markets, and other support services that enhance production on a sustainable basis in addition to providing irrigation water and land. FAO (1997c) pointed out that in our countries have realized the critical role of irrigation in food production, but a number of constraints have been responsible for a relatively slow rate of irrigation development in this region. The constraints are:

- ❖ Relatively high cost of irrigation development,
- ❖ Inadequate physical infrastructure and markets,
- ❖ Lack of access to improved irrigation practice technologies.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the study Area

3.1.1. Location

The study was conducted in Degaluna Tijo Woreda which is located between 6°59' to 8°49N latitude and 38°41'to 40°44'E longitude in Arsi Zone, Oromia Region of Ethiopia as shown below in (Fig.3.1). It is found 298 km far from Addis Abeba along the way from Addis Ababa to Bale and 23km from Assela (Zonal town).

This study area is one of the 24 Woreda's of Arsi Zone of Oromia Region covering a total area of 927 km² (927,000 ha). From this area 43,873 ha is agriculture land, 14,891 ha forest land, 11,285 ha cultivable/ agricultural land while 22,651 ha is for infrastructure area.

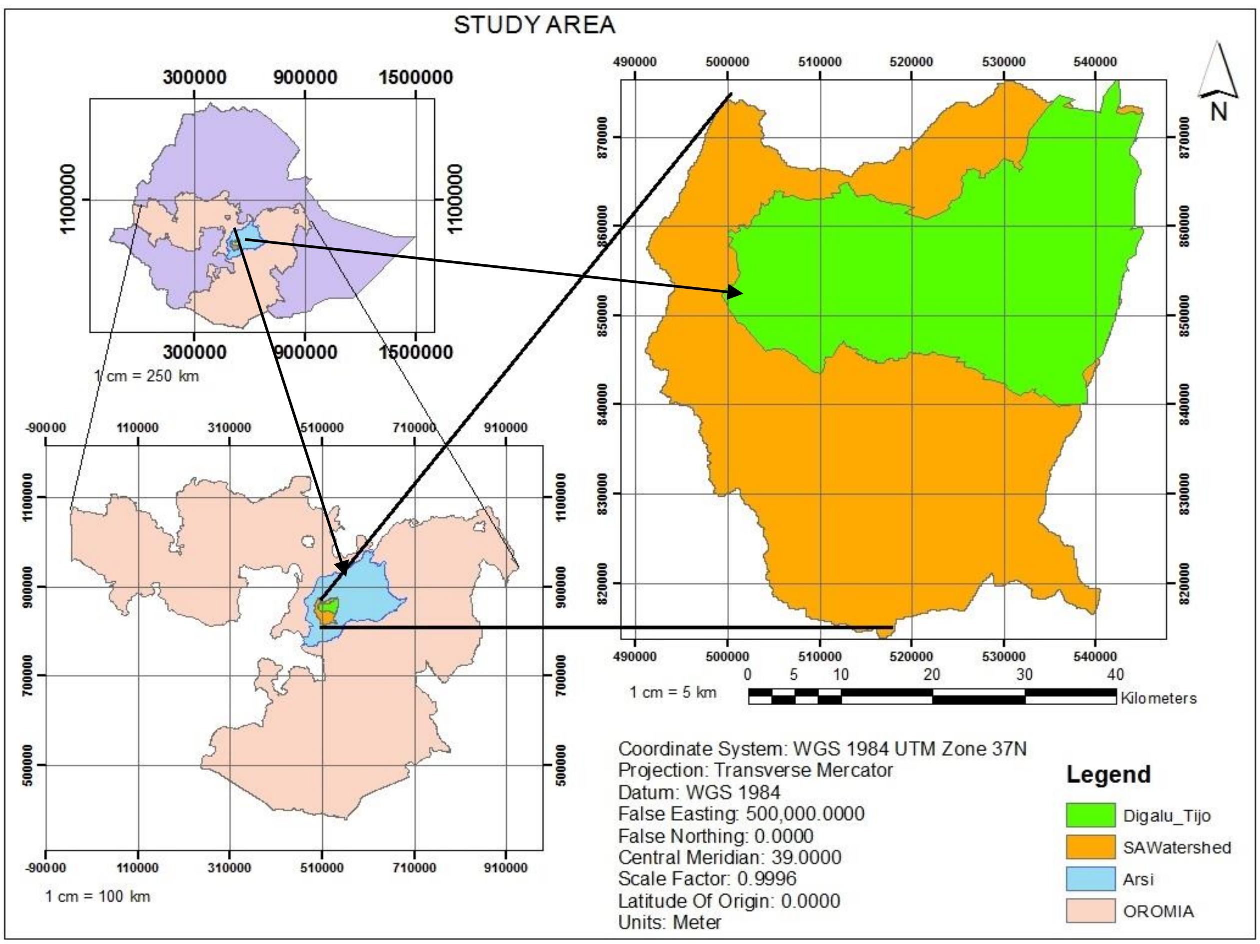

Figure 3.1 Location map of the study area

3.1.2. Rain fall

Ethiopia's rainfall shows high spatial and temporal variability. The highest mean annual rainfall (more than 2,700 mm) occurs in the southwestern highlands, and then it gradually decreases in the north (to less than 200 mm), northeast (to less than 100 mm), and southeast (to less than 200 mm) (World Bank, 2006). The main feature of rainfall in the area is seasonal, normal distribution but variable from year to year. Rainfall distribution over the study area is bimodal, followed by the long and short rainy season that occurs in Jun-October and February-April respectively. The rest of the months are generally dry. Based on the 15 years' from 2001 upto 2015 GC. rainfall data being analyzed the minimum, maximum and average annual rainfall in mm are 900 mm, 1400 mm and 1100 mm respectively. The distribution of rainfall in the town have distributed from March to October. Therefore, the Woreda and its surrounding areas have an advantage of growing different types of cool weather vegetables and producing different types of cool weather crops (Ethiopian Meteorology Agency, November, 2008).

The distribution of rainfall in the town is well distributed from March to October.

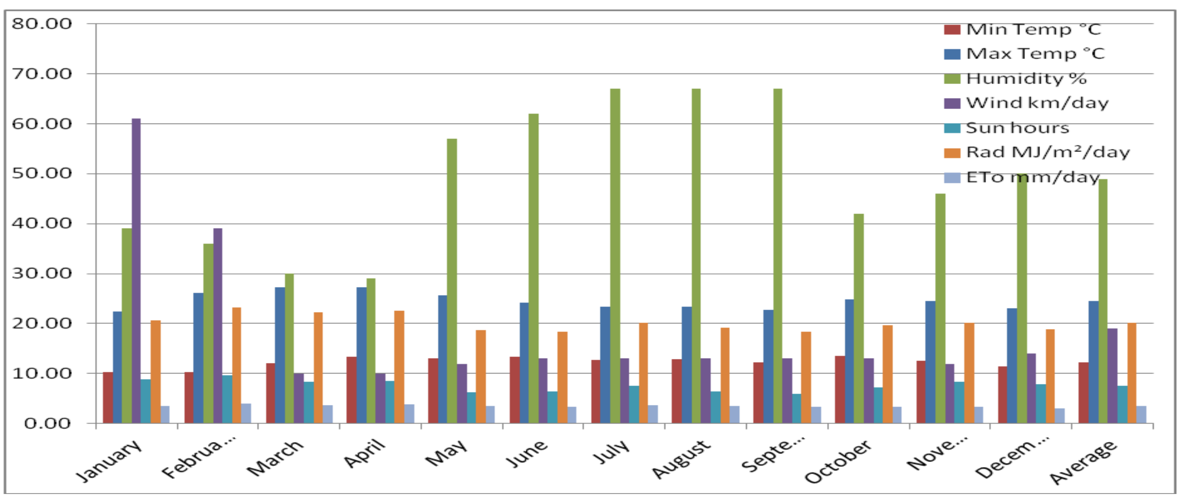

Figure 3.2 Climatic distribution of study area from Kulumsa Metrological station

3.1.3. Temperature

The mean monthly temperature varies from 15^0C in December to 25^0C in May. The lowest temperature over the past 15 years is 13^0C. The average temperature of the Woreda is 14.8^0C and the annual range of temperature from 1991 to 2007 is 6.9^0C. The study area has an average humidity ranging from 33 to 51% over the past 20 years.

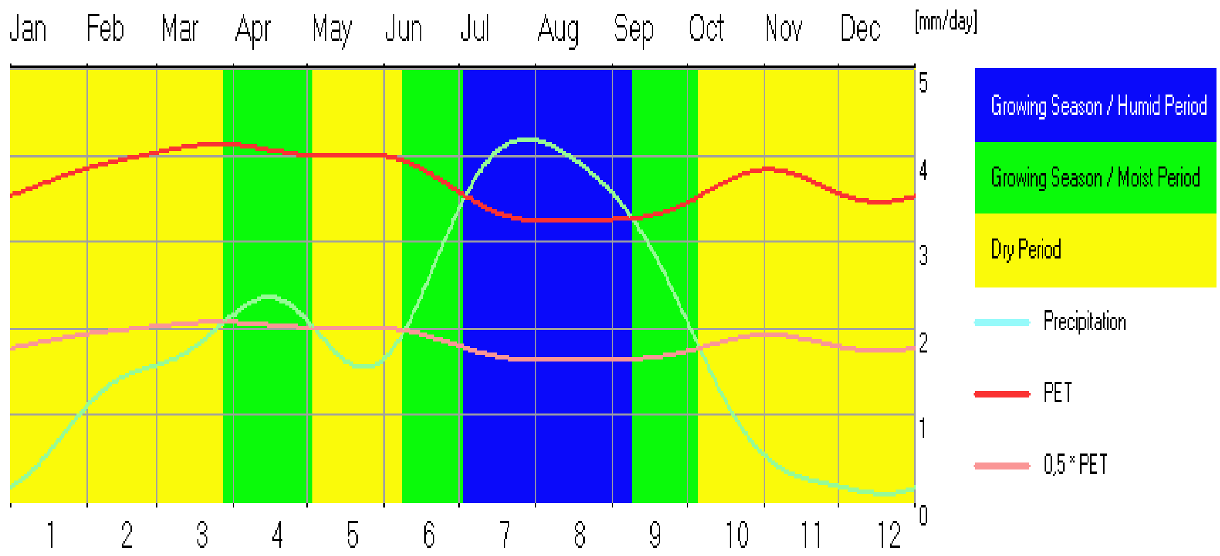

Figure 3.3 Source (New locClim) Degaluna Tijo Woreda growing season

3.1.4. Demographic characteristics and population

The number of population in this Woreda where settlement depending up on the geographical altitude and their argo-ecollogical weather condition, the population can facilitate their settlement depending up on the agricultural and land that suitable for cultivation and the climatologically weather condition division '*Kola'*, *'Dega'*, *'Woyna-dega'* and '*Wurch'*. This climatologically weather condition division determine their cultivation for production of cash crops and others for economic life relative to altitude. The total population of the Woreda is shown in Figure 3.4.

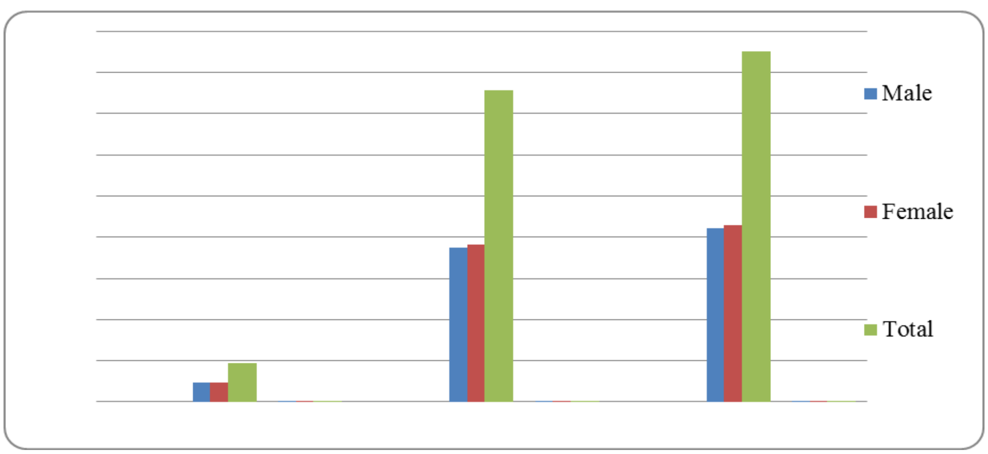

Figure 3.4 Total population of Woreda (CSC, 2007)

3.1.5. Types of crops

The Woreda has about 972,000 ha area, which has two types of climate condition *Dega* and *Woyena Dega* with the altitude ranging from 2000 to 3600 amsl. Because of this two climate zones, the endowed agricultural land and amble weather condition, it is suitable for crop production. The major crops being produced are; teff, wheat, barley, maize, potato, pea, bean and vegetables, and some more, which are not mentioned here, are also cultivated.

3.1.6. Soils

The major soil type in Degaluna Tijo Woreda include red soil which covers 44 % in *Woyna-Dega*, black soil covers 34.5%, dustbowl soil 20.5% and other soil types account for the remaining proportion. Of these soil types, Luvisol, cambisols of lower slopes and fluvisols have huge agricultural potential because of their higher fertility (source**:** Woreda irrigation Authority 2008).

Generally, the fertility status of the soil of Degaluna Tijo Woreda is good and conducive for crop production. Because of this, different types of crops like warm and cool climate adapted crop are produced in the Woreda. This Woreda is especially known in the production of cool weather crops like wheat, beans, pea and barley.

3.2. Sample study irrigation scheme

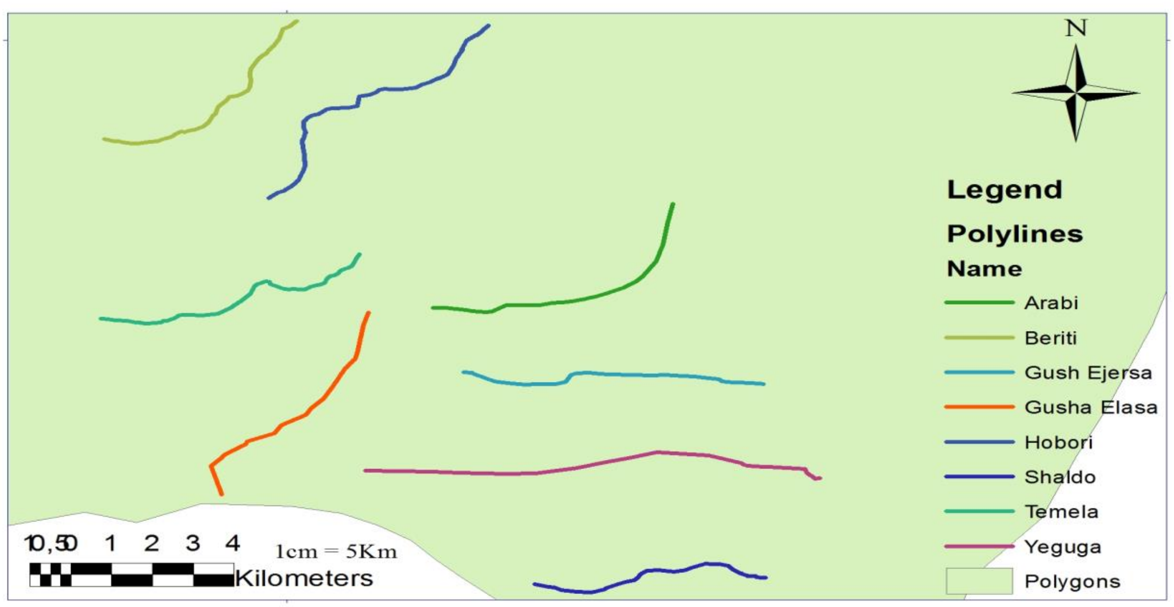

Figure 3.5 Sample selected irrigation scheme for study from Woreda.

3.3. Methodology

3.3.1. Materials used

In this research work, different kinds of software application were used. The application of Remote Sensing on land use and land cover where requires in large sets of data on the geological framework, hydraulic parameters, and geological stresses and measured the land cover changes and other parameter of geographical feature and to locate the study area Arc GIS 10.1 used. These data are stored and presented in many different forms and scales such as maps, graphs, tables, computer databases, or spreadsheets. An arc GIS represents a powerful set of tools that can significantly improve the processing of spatial and raster data.

Soil laboratory is also used to test for the determination of soil grain size distribution using the sieve analysis; field capacity; permanent wilting point; available moisture content and bulk density of soil that help to determines the water holding or amount of that present in the soil at crop root, which is also the way to understand the amount of water dapper collection at root zone as well as the deficiency of irrigation. The potential evapo-transpiration of the area is calculated using the penman-montine method in the CROPWAT 8.0 model (FAO, 1992). The net crop water requirements and the net irrigation requirements are also calculated using the CROPWAT 8.0 model. The effective rainfall is also calculated using the CROPWAT 8.0 model. To assess the economic value of the irrigated agricultural area that can be cultivated and water to be applied to the land we used this one means of identify the beneficiary of irrigation verses to water that can be applied to the field. This indicates that the application method of water into irrigation field resulted good or not.

3.3.2. Methodology

3.3.2.1. Data collection

The primary data collection techniques include field measurement, laboratory result of soil type and grain size distribution and quality and quantity of water can be result discussion with focus point, personal observation. Secondary data were collected form document review from Regional, Zonal and Woreda level irrigation Authorities.

Primary and secondary data collection

The study was conducted during the dry season when the crops are being cultivated under irrigation. The research work was started in the month of October 2016 and continued until end

March 2017. During the study period, regular visits to assess the method of water applications and practices related to water management at the study sites. To achieve the research objective primary and secondary data were collected.

Method of data collection

There are different ways of collecting the appropriate data which differ considerably in context of costs, time and other resources at the disposal of the questioners. Primary data can be collected either through traditionally or through survey. The following survey data collection methods were used for this research purpose:-

Through personal interview: - The investigator follows a rigid procedure and seeks answers to a set of pre-conceived questions through personal interviews. This method of collecting data is usually carried out in a structured way where output depends upon the ability of the interviewer to a good extent.

Secondary data collection

Secondary data were collected from different sources, published and unpublished documents of respective offices and departments, related journals and books. The climatic data were taken from the nearby station (Kulumsa Meteorology Station) nearest to study area were collected from the National Meteorological Agency, Oromia Irrigation Authority, and the other relevant data that desired for identification where collecting from National map Agency.

Primary data collection

Primary field data collection activities include:

- Frequent field observations were made to observe and investigate the method of water applicationsMeasurements of canal water flow at the diversion and field inlet were taken frequently..
- Moisture contents of the soils of the selected irrigation scheme fields before and after irrigations were determined by taking soil samples at different depths of the profiles to assess available water content.

The primary data were obtained through field measurements and/or observations and laboratory analyses which include field topography and configurations, soil data, irrigation delivery and canal alignment, irrigation phases and field irrigation method.

3.3.3. Field survey

On the selected farmers' fields, topographic survey was made by placing takes on the four corners of the plots and taking the elevation of the points using engineers' level. The stakes were also placed 20 meters apart in the flow direction along the furrow. The distance of each point from the field inlet as well as the field dimensions (length of the field in the primary direction of water movement as well as field width) was determined. From this survey, the field slope and its uniformity in the direction of flow and normal to it and area of the field were determined.

3.3.3.1. Sampling methods

Among the number of community based traditional irrigation schemes in Degaluna Tijo Woreda one irrigation scheme from each Kebele was randomly selected for the study based on the accessibility and, experience and type of scheme. Depending up on the above information, out of the 28 kebeles in the Woreda 11 was under the town administration and the rest sat as rural administration. From the remaining 17 rural kebeles the following 8 kebeles were selected for the study: Beriti Irrigation scheme from Beriti Kebele, Gushaa Ejersa Irrigation scheme from Tita Kebele, Gushaa Ellassa Irrigation scheme from Waji Kebele, Afosha Irrigation scheme from Mankula Kebele, Shaaldo Irrigation scheme from Shaldo Kebele, Yeguga Irrigation scheme from Yeguga dergo Kebele Irrigation scheme from Temla Kella Kebele and Hobori Golla Irrigation scheme from Arabi Kebele sample have hold from each kebele that the Irrigation scheme active and irrigation association were selected using the random sampling techniques methods. The sample population was classified in to three groups; this selection depends up on the upper, middle and lower part of the scheme. For data collection, a semi-structured interview and periodic field observations were carried out to survey and examine the distribution network condition, the water applications methods, irrigation practices, water sources, labor availability and practices associated with water management technologies Questionnaire for farmers were split into different categories of interest, upstream, middle stream and downstream. Factor analysis approach preceded by Kaiser-Meyer-Olkin and Bartlett tests was used for identification factors affecting sustainable productivity and water management in the scheme. In Woreda /Division, among 1,255 farmers living in the associations, only 93 farmers were randomly sampl based on the formula proposed by Glenn (1992).

Table 3.1 Sample selection of irrigation field

No	Name of Irrigation	Location	Irrigated area (Ha)	No HH	No beneficiary
1	Hobori	Beriti	35	85	869
2	Gushaa Ejersa	Tita	66	65	789
3	Shaaldo	Shaldo	83.5	105	960
4	Gushaa Elasa	Waji	94.8	360	5260
5	Yeguga	Yeguga dergo	90.6	115	3520
6	Hobori Golla	Arabi	85.6	90	620
7	Afosha	Mankula	92	155	2866
8	Temela	Temla Kella	88.1	280	3150

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

Where: **n** is the sample size

N- Is the size of the total household in study area

e is the precision level chosen

(10% at 90 % Confidence level)

$$n = \frac{1,255}{1+1,255(0.1)^2} = 92.62 \approx 93$$

From the above irrigation scheme, to select the respondent for questionnaire to get additional data to implement the past and current water use, since the member increases and the quality of water decreases in the scheme's association.

3.3.3.2. Field layout, crop selection

In order to evaluate the irrigation water users efficiency of farmers at field level and to compare with each other in the scheme, nine farmers' fields were selected three each from the head, middle and tail end water users of the irrigation scheme with respect to water resource. The criteria for selection of a plot were location (head, middle, and tail), their similarity with water management practices, crop grown and willingness of the farmers to collaborate. The reason for the selection of potato are that it is the dominant and representative crop in which most farms are covered with it because of its production potential and good market in the area. For the present study, potato was grown in the study area during the first growing season of the year 2016.

3.3.3.3. Soil characterization

Soil is a dynamic and heterogeneous material that changes continuously both in time and space. The soil forming process was continuously modified by both environmental and geomorphologic factors. Spatial and temporal variation: spatial variations of soil properties refer to the variation in soil over horizontal distance. Temporal variations in soil properties refer to variations occurring over a time scale. Systematic variability is gradual or distinct change (or trends) in soil properties that can be understood in terms of soil-forming factors or processes at a given scale of observation (Wilding and Drees, 1983).

To differentiate the particle size distribution, the organic matter content and pH, distributed of soil samples were taken from different points at depths of 0-30 cm, 30-60 cm in a zigzag method. After sampling the whole area, samples were mixed thoroughly. To investigate the moisture content of the soil at field capacity (FC), permanent wilting point (PWP) and the bulk density undisturbed soil samples were collected with core samples from the profiles pit excavated at three locations (upper, middle, and tail end of the scheme) up to a depth of 90 cm based on effective root depth of the crop (shallot) at 30 cm depth intervals. These composite samples were transferred to the sample box and were taken to the soil laboratory of Hawassa University and Ethiopian construction design and supervision work corporation research, laboratory and training center for the intended soil analysis.

The textural analysis was done by using hydrometric method. Then the soil textural classes were determined using USDA soil textural triangle (Bouyoucos, 1951). Soil texture refers to the composition of the soil and it was reflected by the particle size, which broadly classified as light, medium and heavy textured soils. During the textural analysis, set of sieves can be used to separate out the sand Silt and clay, while too small grains to sieve, were separated by means of sedimentation in a tall cylinder of water mixed with a dispersing agent. The velocity of settling V is proportional to the square of a particle’s diameter.

pH measurement

PH of the soil was measured by potentio-metrically in the supernatant suspension of 1:1.5, soil: liquid mixture (Staney and Bernard, 1992).

Soil moisture content determination

In Hawassa university soil laboratory, soil samples were analyzed for field capacity (FC) and permanent wilting point (PWP) using pressure plate apparatus at 1/3 and 15 bar, respectively. The soil moisture content measurements before and after irrigation were made by gravimetric method which involves collecting soil samples with auger, weighing the wet soil and the soil samples taken from desire depth at several locations for each soil type. Removing of water by drying in an oven at 105 ^{0}C and re-weighing the sample to determine the amount of water removed. Soil samples were taken to the laboratory six times at three growth stages of the potato and shallot (initial, developmental and maturity) stage per plot. For every eight plots, soil samples were taken before irrigation and two days after irrigation to determine the stored water at root depth from 0 - 30 cm and 31 - 60cm depths per test pit. Soil moisture content in each sample was determined on weight basis using the equation.

$$\theta dw = \frac{Wws}{Wds} * 100 \text{ --- Equ. (3.2)}$$

Where, θdw: - is the soil moisture content on weight basis (%)

Wws: - is the weight of the wet soil sample (g),

Wds :- is the weight of the soil sample after oven drying (g) and then the moisture content of soil samples were converted to the volumetric water content by multiplying with bulk density (ρb) as: $\theta v = \theta dw * \rho b$. Soil moisture content was also expressed in terms of equivalent depth as equivalent depth Total available water (TAW) which is an estimate of the amount of water a crop can use from the soil for the selected fields was computed from the moisture content in volume percent at field capacity and permanent wilting point (Allen *et al*., 1998):

$$TAW\ (mm) = 1000 * (\theta_{FC} - \theta_{PWP}) * Zr \text{ ------------------------- Equ. (3.3)}$$

Where, TAW =is total available water in the root zone (mm),

θFC =is moisture content at field capacity (m3/m3),

θPWP =is the moisture content at permanent wilting capacity (m3/m3) and

Zr =is the root depth (m)

The fraction of TAW that a crop can extract from the root zone without suffering water stress is the readily available soil water:

$$RAW = \tilde{n}\ TAW \text{-- Equ. (3.4)}$$

Where: RAW = the readily available soil water in the root zone [mm],

ñ = Average fraction of Total Available Soil Water

(TAW) = That can bed plated from the root zone before moisture stress

If there are plants growing on the soil, the moisture level continues to drop until it reaches the "permanent wilting point" (PWP). Soil moisture content near the wilting point is not readily available to the plant. The term "readily available moisture" has been used to refer to that portion of the available moisture that is most easily extracted by the plants, approximately 75% of the available moisture.

The potential soil moisture storage depth which is equal to the actual allowable depletion depth in the selected fields just before at the time of irrigation were computed (Walker and Skoerboe, 1987); whereas, actual soil moisture depilation is the actual soil moisture depletion at the time of irrigation and it is the maximum amount of water which can be stored in the root zone at the moment of irrigation without deep percolation loss, TFC and TPWP are soil moisture contents in percent volume at FC, PWP and θBI is soil moisture contents in percent volume before irrigation. The actual soil moisture depletion fraction at time of irrigation was computed using equation (3.4) and compared with the literature value depletion fraction (p) for the crop growth stages which was computed by numerical approximation for adjusting p table value for ($ETc \neq 5$ mm/day) using (Allen *et al.*, 1998). The actual moisture storage or retention (AMS) after irrigation in mm/m was computed as:

$$AMS = 10*[\theta AI - \theta BI] \text{ --------------------------------- Equ. (3.5)}$$

Where, θAI = the actual moisture storage after irrigation in volume percent,

θBI = moisture content of the soil before irrigation in volume percent

The field capacity is the upper limit of available water moisture range in soil moisture and plant relationship. The soil moisture tension at field capacity varies from soil to soil, but it generally ranges from 1/100 to 1/3 atmosphere. Field capacity is determined by pounding water on soil surface in an area of about 2-5m^2 and prevented to drain for one to three days, with surface evaporation prevented.

$$SMD\ (mm) = 10*(\theta FC - \theta BI)\text{----------------------------------} \quad Equ.\ (3.6)$$

Where, SMD is the actual soil moisture depletion at the time of irrigation and it is the maximum amount of water which can be stored in the root zone at the moment of irrigation without deep percolation loss, FC and PWP are soil moisture contents in percent volume at FC, PWP and θBI is soil moisture contents in percent volume before irrigation. The actual soil moisture depletion fraction at time of irrigation is computed using equation (3.6) and compared with the literature value depletion fraction (p) for the crop growth stages which is computed by numerical approximation for adjusting P_{table} value for ($ETc \neq 5$ mm/day) using (Allen *et al*., 1998) equation given as:

$$P = P_{table} + 0.04(5 - ETc) \text{--} \quad Equ.\ (3.7)$$

Bulk density

The core soil samples were dried at 105 °C for 24 hours and the bulk density was then calculated using the following equation.

$$\rho b = \frac{Ms}{Vs} \text{---} \quad Equ.\ (3.8)$$

Where, ρb = soil bulk density (g/cm^3),

Ms = weight of dry soil (g), and

Vs = volume of core sampler (cm^3)

Rooting characterization and moisture use of crop

The amount of soil moisture that is available to a plant is determined by the moisture characteristics of the soil. The soil depth to which the plant root extends and the proliferation or density of the roots soil moisture characteristics, such as field capacity and wilting point are percolate to soil and are a function of the texture and organic matter. Greater possibility lies in changing the characteristics of the plant and root zone amount those enabling the crop to extend its rooting system deeper in to the soil, by elongated its root to reservoir of water. The density of root proliferation is important for the water to contract in to unsaturated region of soil very slowly.

To utilize effectively the moisture stored in the root profile, need good root system to develop during favorable growing period so that make use moisture supply from deeper soil layers. A perennial plant has an already established root depth and needs only to extent its small root and hairs to be able to utilize the amount of available soil water.

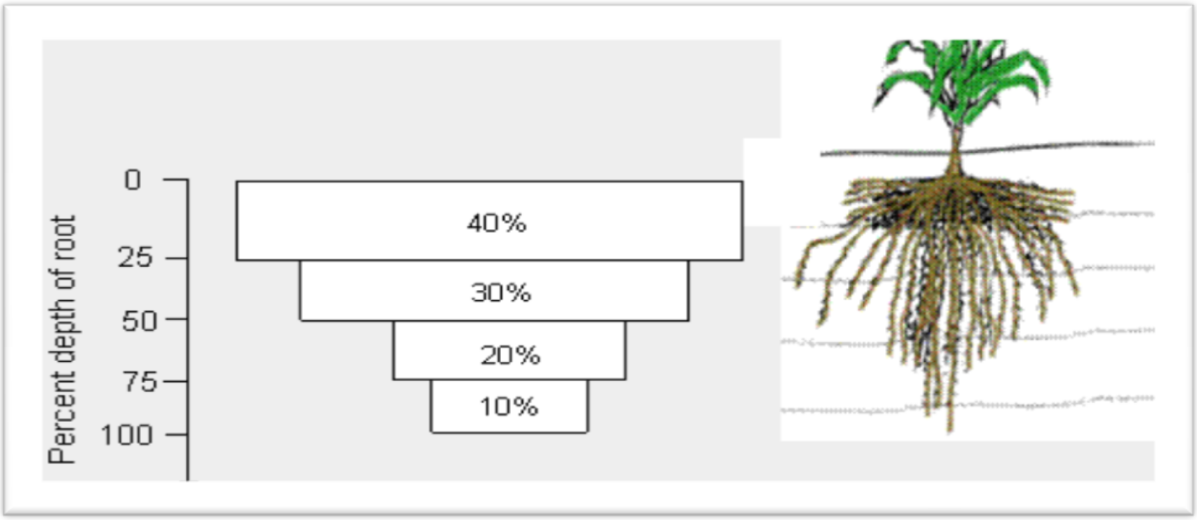

Figure 3.6 Depth of root and their soil moisture depletion zone (Source: irrigation theory and practice A.M. Michael 1978 2nd edition).

The higher water table, shallow soil, and an impermeable formation near the ground surface were the restricting factors of the depth of rooting. Crop management practices, such as cutting the top growth at different physiologic stage, a latter rooting habit.

Table 3.2 The effective root zone depth of some common crops

Rooting characteristics			
Shallow rooted	Moderated deep rooted	Deep rooted	Very deep rooted
Depth of root zone			
40cm	90cm	120cm	180cm
Potato	Tobacco	Cotton	Citrus
Cauliflower	Bean	Surge beet	Coffee
Cabbage	Chili	Tomato	Apple
Lettuce	Castro	Soya bean	Safflower
Onion	Groundnut	Sorghum	Grapevine
	Carrot	Pearl millet	Lucerne

Source: Irrigation theory and practice A.M. Michael 1978 2nd edition.

The root cutting of common crop plants vary widely from soil to soil, for example, root of maize has been found to be extending as deep as 1.5m in medium to course textured soil, while in the fine textured soil the crop has a shallow root system.

3.3.4. Infiltration characterization

To determine infiltration characteristics of the soil in the scheme, double ring infiltrate-meter of 30cm and 60cm inner and outer ring diameters respectively were used at the selected representative three fields (from head, middle, and tail ends of the scheme). Double ring infiltrate-meter was driven to the depth of 15 cm into the soil by hammer. A minimum head of 10 cm was maintained in both rings during measurement. Depths to water levels were measured at increasing time intervals from the datum established on the edge of each cylinder.

3.3.5. Crop water requirement

Crop water requirements is needed to know how much of the applied irrigation water is consumed by the crop. The crop water requirement (CWR) of the major two irrigated crops grown in the irrigation scheme was estimated using CROPWAT 8.0 computer program. The determination of the CWR by the model depends on the determination of the reference evapo-transpiration value using the available climatic data. Fifteen years of mean climatic data for the nearest station (Kulumsa) was used. Data for major crops grown in the study areas including growing stages and stage lengths (days), crop coefficients (Kc), rooting depths (Zr), depletion levels (P), yield response factors (Ky) and planting date were obtained from FAO guidelines (Allen *et al.,* 1998). The irrigation water requirement (IWR) was computed after estimation of effective rainfall by the CROPWAT model using the water budget equation.

$$IR = ETc - Peff \text{---------------------------------------} \quad \text{Equ. (3.9)}$$

Where, IR: -is irrigation water requirement

ETc: - is crop evapo-transpiration (mm/season), and

Peff: - is effective rainfall (mm/season).

Crop growth stage

The stage of crop growth permanently influences the Kc value. The crop growth period can be divided into four distinct growth stages.

- Initial stage: - From the sowing to almost 10% of growth.
- Crop growth: - From 10% of growth 70% of ground cover.
- Mid-season stage: - Including flowering stage and yield formation.
- Late season: - Including repairing and harvesting period.

3.3.6. Flow measurement

The discharge was calculated by the floating method in which the velocity of the water flowing in the main canal was estimated by timing the passage over a predetermined distance 30m of the canal of some material floating on the water surface. The estimated velocity then was multiplied by the cross sectional area of the particular section of the canal to obtain the discharge. The first measurement of discharge was conducted in the upper position of the main canal. Since the main canal had non lined section for part of the system, the test site was ideal for flow measurement. The length of the canal section considered for discharge measurement was taken. Floating material (plant leaf) was put on the upper end of this canal section and the time it took to reach the length of the canal section was recorded. This test was replicated three times and the average time was used. To obtain a per meter velocity, the total length of the section was divided by the average time obtained. The cross sectional area of the canal was also estimated by measuring the average depth and width of this same canal section. Then, by multiplying the cross sectional area (A) with the average flow velocity (V), an average discharge was calculated.

$$Q = \frac{LWS}{t} \text{ ------------------- Equ. (3.10)}$$

Where: Q = discharge flow (m^3/s)

l = lengthe of canal (m),

a = area over which water is applied (m2),

w = width of canal (m),

s = distance between two intevals (m),

t = time taken (s).

3.4. Irrigation scheduling

The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation. 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 and land potential. According to James (1988) and FAO, (1989), improved crop yield or quality, water and energy conservation, and lower production costs are the benefits of proper irrigation scheduling.

In surface irrigation, variations in irrigation depth are only possible within limits. Therefore, it is often sufficient to estimate or roughly calculate 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. Important soil characteristics in irrigated agriculture include:

- The water holding or storage capacity of the soil;
- The permeability of the soil to the flow of water and air;
- The physical features of the soil like the organic matter content, depth, texture and structure; and
- The soil's chemical properties such as the concentration of soluble salts, nutrients and trace elements (FAO, 1989).

Normally farmers use their own experience and indicators (wilting characteristics, soil dryness) to determine when to irrigate (Smith and Munoz, 2002). According to them this has proved not very accurate and a “scientific” advice to farmers on when to irrigate can lead to significant water savings and to a more rational planning of water distribution. Of several methods to determine when to irrigate, “Water indicator” and “Soil budget” are the two widely used techniques (James, 1988). The water budget technique is based on the equation:

$$I = ET - Pe + RO_i + DP_i + L + Drz\,(q_f - q_i) \text{ -------------------- Equ. (3.11)}$$

Where: I= Irrigation requirement;

ET= evapo-transpiration;

L = furrow length (meters)

Pe= effective precipitation (cm);

RO_i, = runoff due to irrigation (cm);

DP_i= deep percolation due to irrigation (cm);

Drz= depth of root zone (cm);

q_f & q_i = final and initial soil moisture contents.

Soil based irrigation scheduling involves in determining the current water contents of the soil, comparing it to a predetermined minimum water content and irrigation to maintain soil water contents above the minimum level. Soil indicators of when to irrigate also provide data for estimating the amount of water to apply per irrigation. Depth of irrigation application is the depth of water that can be stored within the root zone between field capacity and the allowable level the soil water can be depleted for a given crop, soil and climate.

3.5. Technical performance indicators analysis

The performance of traditional irrigation scheme are the degree to which achieve the predicted objectives of the study. Hence, performance evaluations were useful through different tools in order to improve the overall efficiency of the scheme. According to Molden *et al*. (1998), the principal objective of evaluating the performance of irrigation scheme was identified the irrigation practice and water distribution management among the scheme to improve the implemented application efficacy of irrigation. The evaluations of surface irrigation at field level were important feature in terms of both managing and efficiency of the irrigation scheme. The types of performance measures (indicators) to be chosen depend on the purpose of the performance assessment activity (Molden *et al*., 1998). With these indicators, the amount of deviation between the actual values against the intended are evaluated.

3.5.1. Properties of performance indicators

A true performance indicator includes both an actual value and an intended value that enables the assessment of the amount of deviation. It further should contain information that allows the manager to determine if the deviation is acceptable. Some of the desirable attributes of performance indicators suggested by Bos (1997) are:-

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

The indicators must be quantifiable: the data needed to quantify the indicator must be available or obtainable (measurable) with available technology.

Reference to a target value: this is, of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator. These target values and their margin of deviation should be related to the level of technology and management (Bos *et al*, 1991).

Provide information without bias: ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain value decisions.

3.5.2. Performance evaluation of traditional irrigation

The principal objective of evaluating surface irrigation systems is to identify management practices and systems that can be effectively implemented to improve the irrigation efficiency. Evaluations are useful in a number of analyses and operations, particularly those who are essential to improve water management and control. Evaluation data can be collected sometimes from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year (FAO, 1989)**.** It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement (Jorge, 1993). The evaluation of surface irrigation at field level is an important aspect of both management and design of the system.

The performance of farm irrigation is determined by the efficiency with which water is diverted, conveyed, and applied; and by the adequacy and uniformity of application in each field on the farm. These parameters have been subdivided and defined in a multitude of ways as well as named in various manners. Common performance indicators defined by Kloezen and Garces-Restrepo (1998), based on literature include:

- ❖ Conveyance efficiency, distribution efficiency, field efficiency, application efficiency and project efficiencies;
- ❖ Reliability and dependability of water distribution;
- ❖ Equity or spatial uniformity of water distribution; and
- ❖ Adequacy and timeliness of irrigation delivery.

3.5.3. Conveyance efficiency

Water conveyance efficiency is used to measure the efficiency of water conveyance system associated with the canal network, water courses and field channels; it is also applicable where the water is conveyed in channels from the river to the individual fields. It is one of the several closely related and commonly used output measures of performance that focus on the physical efficiency of the water conveyance by the irrigation system (Bos,1997). Conveyance losses are primarily dependent on the wetted perimeter of the canals and not on the volume of water conveyed. Thus, they are considered to be fixed for all parts of the irrigation system. Based on Ramulu (1998) conveyance efficiency can be defined as follows.

$$Ec=\frac{Wf}{Wd}*100 \quad \text{---Equ.(3.12)}$$

Where: Ec = conveyance efficiency (percent);

Wf = water delivered to the irrigated plot (at the field supply channel) (m^3/sec); and

Wd = water diverted from the source (m^3/sec).

The conveyance efficiency (Ec) mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of the canals. In small irrigation schemes, more water is lost due to an earthen embankment canal system. From canals in sandy soils more water is lost than from canals in heavy clay soils; when canals are lined with bricks, plastic or concrete, only very little water is lost. If canals are badly maintained, bund breaks are not repaired properly and rats dig holes, a lot of water is lost. According to the Brouwer and Prins (1989), the conveyance efficiency for long unlined canals (>2000 m), have been reported as 60, 70, 80% for sand, loam, and clay soil respectively; for medium length unlined canals (200-2000) as 70, 75, 85% for sand, loam and clay soil respectively; and for short canals (<200 m) as 80, 85 and 90% for sand, loam and clay soil respectively. The efficiency of lined canals has been reported in the order of 95% for all canal length.

3.5.4. Application efficiency

Water application efficiency provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. The objective is to apply the water and to store it in the crop root zone to meet the crop water requirement (Odhiambo and Kranz, 2011). Water application efficiency is a measure of the fraction of the total volume of water delivered to the farm or field to that which is stored in the root zone to meet the crop evapo-transpiration needs. According to (FAO, 1989) application efficiency is the most important in terms of design and management since it reflects the overall beneficial use of irrigation water and it expressed as a percentage.

$$Ea = \frac{\text{Depth of water applied to the field (cm)}}{\text{Depth of water added to root zone (cm)}} * 100 \text{ --------------------Equ.(3.13)}$$

To compute application efficiency, it is necessary to identify at least one of these losses (deep percolation and field tail water or run off) as well as the amount of water stored in the root zone. This implies that the difference between the total amount of root zone storage capacity available at the time of irrigation and the actual water stored due to irrigation be separated, i.e. the amount of under-irrigation in the soil profile must be determined as well as the losses (FAO,1989). Kenneth (1988) indicated that attainable water application efficiencies varied greatly with irrigation system, type and management, and suggested that the attainable application efficiency for surface irrigation were in the order of 80-90%, 70-85% and 60-75% under basin, border and furrow type of system respectively. While FAO (1989) suggested 60% attainable water application efficiencies for surface irrigation method. Also Norman (1999), said that a minimum value of the ratio of crop water demand to the actual amount of water supplied to the field (or irrigation efficiency of 60%) was included in the design of most surface irrigation systems to accommodate crop water needs and anticipated losses. Value below this limit would normally be considered unacceptable. Lesley (2002) suggested that it could be in the range of 50-80%. In general, according to Michael (1997), water application efficiency decreases as the amount of water applied during each irrigation increase. All these components can then be used to estimate the application efficiency, the uniformity of the application, the adequacy of the application, and the effectiveness of the irrigation in meeting the target application.

3.5.5. Water storage efficiency

According to Michael (1997), irrigation water use efficiency is the ratio between the volume used by plants through evapo-transpiration process and the volume that reaches the irrigation plots and indicates how efficiently the available water supply is being used, based on different methods of evaluation. The design of the irrigation scheme, the degree of land preparation, and the skill and care of the irrigators are the principal factors influencing irrigation efficiency. Identifying the various components and knowing what improvements can be made is essential to making the most effective use of this scarce resource. The most common way to express the efficiency of irrigation systems is to section it into conveyance and application efficiencies. Once the conveyance and field application efficiency have been determined, the scheme irrigation efficiency (Es) can be calculated, using the following formula (FAO, 1989).

$$Es=\frac{Ea}{Ec}*100 \text{ ---Equ.(3.14)}$$

Where: Es= is scheme irrigation efficiency (%),

Ec =is conveyance efficiency (%), and

Ea =is field application efficiency (%)

According to FAO (1989), a scheme irrigation efficiency of 50–60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20–30% is considered to be poor. The performance of farm irrigation is determined by the efficiency with which water is diverted, conveyed, and applied; and by the adequacy and uniformity of application in each field on the farm. These parameters have been subdivided and defined in a multitude of ways as well as named in various manners. Common performance indicators defined by Kloezen and Garces Restrepo (1998), based on literature include: conveyance efficiency, supply efficiency, field efficiency, application efficiency and project efficiencies; reliability and dependability of water distribution; and adequacy and timeliness of irrigation delivery.

3.5.6. Distribution uniformity

Distribution uniformity is a measure of how consistently water is applied during an irrigation event. This uniformity of application can have a considerable effect on crop yield and optimum water application. There are several interpretations in the literature, but a common measure for surface irrigation systems is to divide the average depth infiltrated calculated from the quarter of the field with the lowest infiltrated depths, by the average infiltrated depths. When a field with a uniform slope, soil and crop density receives steady flow at its upper end, a water front will advance at a monotonically decreasing rate until it reaches the end of the field. Application uniformity concerns the distribution of water over the actual field. A number of technical sources suggest the Christiansen coefficient as a measure of uniformity.

$$Du=\frac{\text{Minimum infiltration depth}}{\text{Average infiltration depth}} \text{ --------------------------------Equ.(3.15)}$$

Merriam and Keller (1978) proposed that distribution uniformity be defined as the average infiltrated depth in the low quarter of the field, divided by the average infiltrated depth over the whole field. Thus, the evaluator can choose one that fits his or her perceptions but it should be clear as to which one is being used. One indictor used to represent the pattern of the infiltrated depths along the field length is the distribution uniformity (Kruse, 1978) cited by Jurriens *et al*. (2001), which is defined as the minimum infiltrated depth (Dmin) divided by the average infiltrated depth (Da), FAO (1992) suggested that the average distribution efficiency DU of 65% as sufficient and DU of 30% as poor.

3.5.7. Christiansen uniformity coefficient

The uniformity of application is evaluated using Christian uniformity coefficient (Jurriens *et al*., 2001). This is given as:

$$Cu = 100\left(1-\frac{\sum_{i=1}^{n} |d|}{n\tilde{X}}\right);\ d=Xi-\breve{X} \text{-- Equ. (3.16)}$$

Where, Cu = Christianson uniformity coefficient (%),

d = deviation of observation from the mean (cm),

n = number of observations,

$\ddot{X}$= average depth infiltrated (cm), and

Xi = depth of infiltrated at observation point i (cm)

3.5.8. Relative water supply and relative irrigation supply

As Molden *et al*. (1998) cited, relative water supply(RWS) as presented by Levine (1982) and relative irrigation supply (RIS)as developed for this indicator set are used as the basic water supply indicators are total crop water demand supply (Perry 1996).

$$\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Crop demand}} \text{--------------------------------- Equ. (3.17)}$$

$$\text{Relative irrigation supply} = \frac{\text{Total irrigation supply}}{\text{Irrigation demand}} \text{------------------------- Equ. (3.18)}$$

3.5.9. Water supply indicators

According to Molden *et al*. (1998), states that the water supply indicators (relative water supply, relative irrigation supply, and water delivery capacity) are better suited to place the irrigation system in its physical and management context. Higher values of these indicators indicate a more generous supply of water. Where the water supply indicators show a lower value it indicates a situation of a more constrained water supply and values of productivity per unit of water are more important. According to Bos et al., (1994), these indicators deals with the primary task of irrigation managers in the capture, allocation and conveyance of water from source to field by management of irrigation facilities. Indicators address several aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation canal to keep the system running efficiently, and the service aspects of water delivery which include such concepts as certainty and equity.

3.5.10. Determination of deep percolation ratio

Since the furrows are closed end, runoff ratio is neglected. The loss of water through drainage beyond the root zone is reflected only in the deep percolation ratio that expresses the ratio between the percolated water beyond the root zone to the volume of water applied to the field. Also the evaporation from the soil is marginal and can be neglected because it is only a short period after irrigation. Therefore, deep percolation ratio was calculated for selected eight test plots as:

$$DPR = 100 - Ea \quad (3.19)$$

Where, DPR = Deep percolation ratio,

Ea = application efficiency in percent

3.5.11. Water delivery capacity ratio

The same authors mentioned that water delivery capacity is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands. Again, a lower or higher value may not be better, but needs to be interpreted in the context of the irrigation system, and in conjunction with the other indicators. Values much greater than 1 indicate that their capacity is not a constraint to meeting crop water demands. Values close to 1 indicate that there may be difficulties meeting short-term peak demands.

According to Molden *et al.* (1998), water delivery capacity ratio can be expressed as:

$$\text{Water delivery capacity} = \frac{\text{canal Capacity to deliver water system at head}}{\text{Peak consumptive demand}} \text{-----------------} (3.20)$$

Where,

Capacity to deliver water at the system head = the present discharge capacity of the canal at the system head, and

Peak consumptive demand = the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system.

3.5.12. Estimation of water productivity

To compare the relative water productivity of the farmer`s field at three locations (head, middle and tail), yield of the shallot was collected from each of the eight selected fields. Then the collected yield from each field was weighed. After determining the amount of water applied and estimating amount of water consumed by crop through process of evapo-transpiration in a season, the water productivity in terms of water use efficiency index was computed using equations (3.6 and 3.8). The local market price at Sagura Woreda's Town during the time of harvest was used to evaluate water productivity on monitory units.

3.6. Irrigation land suitability factor

Land evaluation is primarily the analysis of for water application evaluation and sustainability we consider soils, climate, vegetation, and etc in terms of realistic alternatives for improving the use of that land. For irrigation, land suitability analysis, particular attention is given to the physical properties of the soil, to the distance from available water sources and to the terrain conditions in relation to methods of irrigation. Slope gradients in almost flat terrain are often overestimated. In open plains, slope gradients of 0.2 percent are usually clearly visible. The proper recording of negligible slope-gradient variations is important, especially for erosion, irrigation and drainage.

3.7. Soil

Soil is the natural material that covers the land surface of the earth. Soils have profiles, constituting of specific kinds and combinations of horizons, as well as specific surfaces and relief or landscape features. Where applicable, the soil climate classification should be indicated; the soil moisture and temperature regimes according to Keys to Soil Taxonomy (USDA Soil

Survey Staff, 2003). They are formed by a combination of natural processes under the consistent influences of climate (Temperature, moisture, periodic distribution), biotic factors (plants, animals, and microbes), topography (slope position, aspect, shape and amount), parent material (rock, alluvium), and time (how long the soil has been forming). It is common to associate the traditional zones with elevation and temperature and try to recognize agro climatic and vegetation zones.

3.8. Water performance analysis

This helps to assess the financial income or the beneficiary of the irrigated land that farmers or assassination can be cultivated in their irrigated command area.

$$\text{Output per cropped area tons (Ha)}=\frac{\text{Production}}{\text{Irrigated cropped area Ha}} \text{ ---------------Equ.}(3.21)$$

$$\text{Output per unit command}\left(\frac{\text{Birr}}{\text{Ha}}\right)=\frac{\text{Production}}{\text{command area Ha}} \text{ ---------------------Equ.}(3.22)$$

$$\text{Output per unit water consumed }\left(\frac{\text{Birr}}{\text{m3}}\right)=\frac{\text{Production}}{\text{water comsumed by ETo}}\text{---Equ.}(3.23)$$

3.9. Slope

Slope is the site inspection of inclination or gradient of ground surface that makes to vary from the gentle ground surface is commonly expressed in percent. Slope is important for soil formation, irrigated land recommendation and management because of its influence on runoff, drainage, erosion and choice of irrigation types.. According to (MOA), the inclination of land having a slope greater than 30 percent inclination cannot be cultivated. According to FAO standard guidelines for the evaluation of slope gradient shows that slopes which are less than 2%, are very suitable for surface irrigation, and slopes which are greater than 8%, are not generally recommended for irrigation purpose (FAO, 1999).

3.10. Methods of data analysis

Analysis of performance indicators:- conveyance efficiency, water application efficiency, storage efficiency (adequacy), distribution uniformity, Christiansen's uniformity coefficient and deep percolation ratio were initially calculated using MS Excel and Arc GIS, CROPWAT8.0 computer program, soil test laboratory, as well as using Equation 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, up to 3.23 respectively. To assess the performance of traditional irrigation system that found in Woreda 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 good output of a system. Performance indicators are developed related to the irrigation water use and irrigated command area and the result of crop production output. The major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users.

The adequacy indicator shows to what extent is the quantity of water provided sufficient for the crop growth needs to relative water supply. Irrigation production performance indicators include cropping intensity, ratio of area planted and area harvested, annual yield, productivity of land and water. Equity is any irrigation distribution system, which practices equity in water allocation and distribution, will have uniformity in the cropped area along the distribution system.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Analysis of soil physio-chemical properties of the study area

To investigate some of the physical properties of soil in the site (moisture content at field capacity (FC) and permanent welting point (PWP), and available soil moisture content before and after irrigation, organic matter content, pH, texture, and bulk density), for the purpose of understanding the general feature of the irrigated soil type, different field observations were taken and analyzed.

4.1.1. Particle size distribution

Based on soil sample taken the laboratory analysis of soil particle size distribution, were dominant by textural class was found to be clay to clay loam. Summary of the result is presented in Table 4.1.

Table 4.1 Particle size distribution (soil texture)

	Soil Sample Location					
Soil properties	Up Stream		Middle Stream		Down Stream	
Soil depth (cm)	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Sand%	80.90	37.36	23.73	34.44	29.00	17.37
Clay%	2. 12	25.92	40.25	29.61	39.68	61.44
Silt%	16.93	36.72	36.02	35.95	31.32	21.19
Texture	S. Loam	Loam	Clay	Clay Loam	Clay Loam	Clay

As the result indicate that, the textural soil class of the upstream field affected by sandy soil relative to middle and downstream. Sandy soil has less water holding capacity resulted to less amount of crop production, this also factor of maximum day for water application time.

4.1.2. Bulk density

The bulk density of soil of the study area observed a variation with depth in table 4.3. It ranges between 1.33 to 1.43 g/cm^3 and generally the top surface soil had lower bulk density than the subsurface. The top 0-30 cm had an average bulk density of 1.38 g/cm^3 whereas; the subsurface (30-60 cm) had an average bulk density of 1.41 g/cm^3 respectively. The weighted average bulk density of the soil in the study area was found to be 1.40 g/cm3**.** The result obtained from subsurface showed a little higher than values for clay soils. This might be attributed to relatively low organic matter content and compaction effect due to overlaying material at the depth of 30 - 60 cm. Miller and Donahue (1995) recommended soil that have bulk density less than 1.4 gm/cm^3 for clays and 1.6 gm/cm^3 for sands in order to get better plant cultivation.

4.1.3. Soil moisture content

The soil moisture content at field capacity in Table 4.2 varied from 35.29% to 38.85% by mass. The soil moisture at permanent wilting point varied from a minimum value of 18.23% to the maximum value of 20.83% by mass basis. The total available water amount varied from the lower value of 104.04mm/m at the surface to the high value of 185.58mm/m at the sub surface.

Table 4.2 Soil moisture content and Bulk density

	Up stream		Middle		Down stream	
Depth	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Field capacity% (0.33bar)	38.85	35.29	33.85	36.01	29.74	35.36
Field capacity (v/v)	45.53	47.89	42.04	46.45	40.3	46.36
Permanent wilting point % (0.33bar)	18.23	19.5	20.25	20.83	18.18	19.9
Permanent wilting (v/v)	21.37	26.46	25.15	26.87	24.63	26.09
B/D (g/cm3)	1.172	1.357	1.242	1.29	1.36	1.311
AMC %	20.62	15.79	13.6	15.18	11.56	15.46
TAMC %	185.58	142.11	122.4	136.62	104.04	139.14

4.1.4. Soil pH

The pH of the soil of study area varied with depth and had a tendency of increasing from surface toward the sub surface. The average pH was about 6.85 at the surface (0-30 cm) and 6.97 at the subsurface (30-60 cm). The weighted average pH of the soil was found to be 6.91. This indicates that, the pH of the study site is nearly neutral and suitable for crop production.

4.1.5. Soil organic carbon and organic matter content

The result of the soil samples collected from the study area indicated that, the organic matter content of soil declined as the depth increased as shown in table 4.4. The percent of organic carbon estimated were varied from 3.14% to 6.19 %. The organic matter content obtained by multiplying with the conversion factor of (1.724) varied from 2.88 to 4.47%. The average organic matter contents were estimated as 5.42% at the surface (0-30 cm) and 10.67% at subsurface (30-60 cm). The weighted average organic matter content of the soil was found to be 8.58%. It was found high in top soil within the depth range 0-30 cm and less in subsurface soil within the depth range of 30-60 cm. The values indicated that the soil had low organic matter content based on the range given by Landon (1991), the detail of Soil pH, soil organic carbon and organic matter content of the study area given in Table 4.3.

Table 4.3 Soil pH, soil organic carbon and organic matter content

Soil Sample Location						
	Up Stream		Middle		Down Stream	
Soil depth (cm)	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
pH	5.36	5.56	5.4	5.52	5.46	5.86
Organic Carbon %	6.19	4.98	3.99	5.55	4.13	3.14
Organic matter %	10.67	8.58	6.88	9.57	7.12	5.42

This could be one of the reason for farmers to loss their interest of cultivation, so some of their land not produce crop production accordance of the expected result. According to Landon (1991) the organic matter content of cultivation land classified in Table 4.4.

Table4.4 Classification levels for different elements in soil (Landon; 1991)

	Very Low	Low	Medium	High	Very High
pH		<5.5	5.5-7.0	>7.0	
CEC (meq/100g)	<5	5-15	15-25	25-40	>40
Base saturation (%)		<20	20-60	>60	
OM (%)		<4	4-10	>10	

So to solve the unsatisfied organic matter content, farmers' use different mechanisms to assemble the soil fertility in to normal condition. The farmers of the study area used UREA, DAP and animal dung in farms having low organic matter to sustain crop yield for continues crop cultivation.

4.1.6. Soil infiltration rate

The infiltration rate was measured at (head, middle and tail end of three test plots) to determine the infiltration characteristics of the soil using double ring infiltro-meter as labeled in Section 3.2.4.4 and mean data calculated from the study field is presented in figure 4.2. From the result obtained the basic infiltration rates were found 9.6 mm/hr, 11.8 mm/hr and 10.0 mm/hr at head, middle and tail end of test plots, respectively. The average basic infiltration rate of the field plots was measured as 10.25 mm/hr. According to Kay (1986), the basic infiltration rate of a soil in the range of 1-10 mm/hr, is classified as a soil with low infiltration rate which is the typical characteristics of clay textured soil. This value in middle location of test plots was slightly more than the range. This might be due to low amount of organic matter content of the test plots as present in Table 4.5 above, nutrient availability and poor management practice of the land.

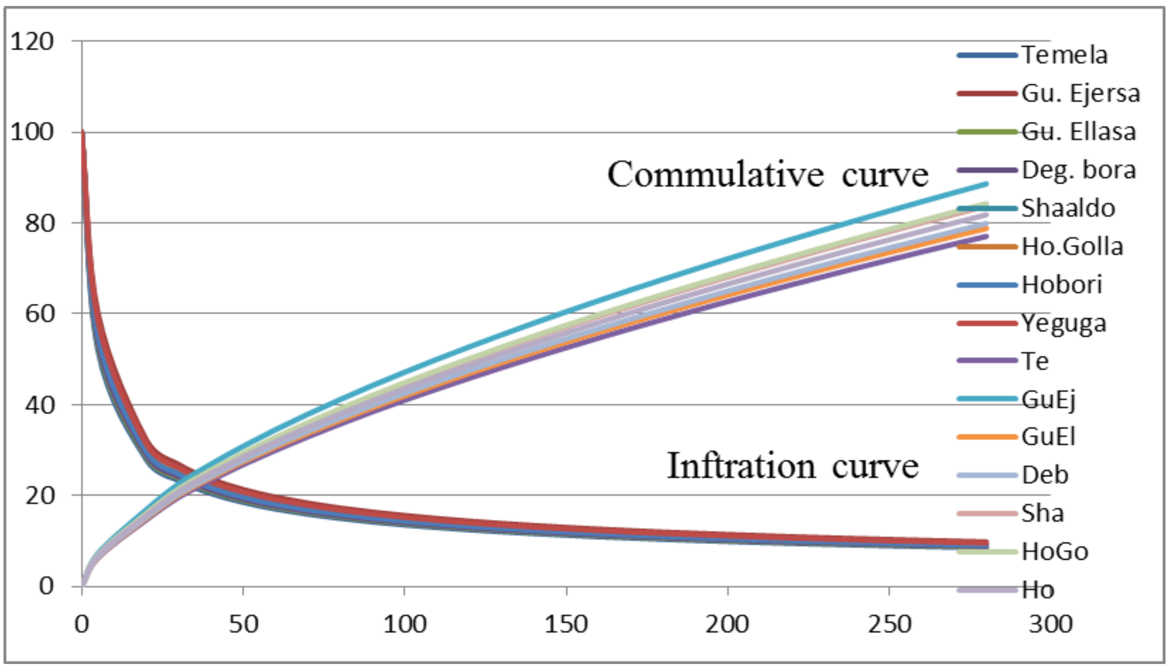

Figure 4.1 Infiltration rate curves Gusha Temela scheme

Note:- Gu.Ejersa for inftration curve
GuEj for commulative curve

4.2. Rain fall

The Rainfall distribution over the study area is bimodal, followed by the long and short rainy season that occurs in Jun-October and February -April respectively (see on appendix table-5). The rest of the months are generally dry. Based on the analysis of the 15 years' rainfall data the minimum, maximum and average rain fall in mm are 900 mm, 1400 mm and 1100 mm respectively. This indicates that Degaluna Tijo Woreda has a very long rainy season. The distribution of rainfall around study area were distributed humid period from let May to beginning of October, moist period from beginning of February to mid May and beginning of October to mid October and dry period from mid October to beginning of February.

4.3. Crop water requirement

For crop water requirement and irrigation water requirement computed from the climatic data were used to estimate the crop water productivity in terms of water consumed and also utilized as cross check for the irrigation requirement obtained from soil moisture analysis and FAO (1984) defined crop water requirements as ‘the depth of water needed to meet the water loss through evapo-transpiration of a crop, growing on the fields under non restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment. In absence of reports on onion irrigation water requirements, the calculation was made by taking the crop coefficient (Kc) an input data to run the program. The scheme irrigation requirement was calculated with CROPWAT 8.0 using the climate data, cropping pattern, planting dates, and area coverage of individual crop for the cropping season of 2016/2017 to determining the peak irrigation water requirement and the peak demand of irrigation water supply. The net irrigation requirements of the scheme and irrigation requirements for actual area irrigated results obtained from the CROPWAT 8.0 are presented in Table 4.6.

Table 4.5 Crop water requirement

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Potato 65%	117.70	50.90	-	-	-	-	-	-	-	34.40	46.80	108.60
2. Cabbage crucifers 10%	56.10	77.40	69.10	113.70	8.50	-	-	-	-	-	-	-
3. Sweet Peppers 9%	110.50	38.40	-	-	-	-	-	-	-	41.90	41.20	96.10
4. Tomato 9%	123.30	104.80	4.90	-	-	-	-	-	-	41.90	42.20	103.20
5. Small Vegetables 7%	39.40	-	-	-	-	-	-	-	-	49.50	59.40	99.20
Net scheme irr.req.												
in mm/day	3.40	1.90	0.20	0.40	-	-	-	-	-	1.10	1.40	3.10
in mm/month	105.10	52.70	7.30	11.40	0.90	-	-	-	-	33.40	42.30	95.50
in l/s/h	0.39	0.22	0.03	0.04	-	-	-	-	-	0.12	0.16	0.36
Irrigated area (% of total area)	100.00	92.00	18.00	10.00	10.00	-	-	-	-	90.00	90.00	90.00
Irr.req. for actual area (l/s/h)	0.39	0.24	0.15	0.44	0.03	-	-	-	-	0.14	0.18	0.40
55ha	11.70	6.60	0.90	1.20	-	-	-	-	-	3.60	4.80	10.80
55ha for 8 Hr	93.60	52.80	7.20	9.60	-	-	-	-	-	28.80	38.40	86.40
55ha for 12 Hr	140.40	79.20	10.80	14.40	-	-	-	-	-	43.20	57.60	129.60
95ha	27.30	15.40	2.10	2.80	-	-	-	-	-	8.40	11.20	25.20
95ha for 8 Hr	218.40	123.20	16.80	22.40	-	-	-	-	-	67.20	89.60	201.60
95ha for 12 Hr	327.60	184.80	25.20	33.60	-	-	-	-	-	100.80	134.40	302.40

The total area of irrigation water requirement was depending up on size of command area. During field observation the identification of command area categorized from 30 hectare up to 70 hectare. Depending on this the minimum and maximum water requirement for irrigation of one plot 140.40 l/s and 327.60 l/s respectively, so this amount of water to be available at field inlet.

4.4. Conveyance system

The command area of the scheme was divided into sub- units. This also further subdivided into small units depending upon the individual cultivated farm size, due to the fact, the alignment of the scheme life was very long, it not good to deliver enough amount of water into farm or cultivable command area. As frequent field observation of study area it was observed that, all alignments of canal where filled with silt deposit which may be originate and transported from upper part of the catchment area, this sediment load can be affect the flow of water after rain season occurs around upstream catchment area of the canal. Due to those influences there will be water canal change into gorge, discontinues service and application of irrigation water overtop occur until the allowance of water canal to be ended.

Based on field observation the condition of most earthen canal which are found damaged or not properly function. It was observed that, the lands irrigated by earthen canal were under the risk of frequent flood damage that coming from the upper catchment during rainy season. Development agent and farmers living in the locally responded that, especially at the time of heavy rainfall farmers could not be able to grow any crops on those areas because of water clogging. The main earthen canal has been distorted a total length of 1.8km to 3.53Km.

Figure 4.2 Main canals and head work of Gusha Elasa irrigation system.

The water application system from the main earthen canal to the field was based on rotation. The main earthen canal is under a serious threat of collapse because of the damage of the two sides of banks due to animal cross, a large street, animal boring hole also large plant root composed and upper catchment run off trough the rapidly advancing river bank. The method of farmers water diverting and closing water in to the fields are traditional system. This water diverting system is not good as it destruct field canal and creates a gorge, the field especially at day time increasing the water loss along main earthen canal when cross the small gorge. The water intake system at the head work of earthen canal does not properly functioning as it is constructed from natural materials and lack of maintenance and handling. Abstraction using water loss even out of irrigation scheme areas was observed and there is no water controlling method along the main canals, this also increase the loss of canal efficiency.

Figure 4.3 Main canals and head work of Shaldo irrigation system.

4.5. Water distribution and management system

The scheme was constructed to deliver irrigation water to individual fields based on proportional flows throughout the irrigation season. Actual water delivery service to irrigators was certainly rotational, but with unknown exact date and volume since there is no water measuring mechanism or method found in the scheme. Irrigation water was managed by Water User Association (WUA), Water User community (WUC) and Water User group (WUG) who have the overall authority to administer and control the irrigation water management and utilization. The water user association had six executive members and one chair person. The main unlined canal and sub-unlined were operated by the three water distributers locally called “Ittiggaaftamma bishaani gareedhaa” in Afan Oromo, who had been elected by the member of beneficiaries from upstream, middle and downstream of the scheme based on the proximity to the water source, responsible for water distribution among users. The “Ittiggaaftamma bishani gareedhaa” has the authority to offer water for each farmer on the priority of the crop condition as requested by farmers in their groups**.** The water that the farmers used to irrigate their farmland did not have any charge. The canals were maintained or cleaned by the farmers at the end of rainy season or annual period then after completing canal cleaning them released water until the end of the crop season. Each plot holder is responsible to operate the scheme during his turn. It supposed to check the distribution of water to field starting from his plot to the outlet. Farmers usually used to irrigate their fields every 13 to 27 days, which is not depending on the crop type and crop water requirement in each crop stage and availability of water irrigation.

4.6. Conveyance efficiency (Ec)

The main canal conveyance efficiency was estimated using measured discharges at from 450m up to 150 m intervals for some irrigation. The average conveyance efficiency for main unlined canals was found to be %. During measurement, sources of losses from main unlined canal were observed by leakage losses through seepage, logging and mouse hole water leakage. Main unlined conveyance efficiency and water loss from main canal were observed by leakage losses through seepage and mouse hole. For main canal, the main losses were observed through seepage, mouse hole and deep percolation due to some gorge and types of soil which canals would be cross. The average conveyance efficiency value for the different field canals (Field-1), (Field-2) and (Field-3) were found to be 84.39%, 73.46 % and 82.05%, respectively.

Table 4.6 Main canal conveyance efficiency and water loss rate at Gusha Elasa

Canal type	Segment No	Distance b/n points(m)	Inflow l/se	Out flow l/se	Conveyance loss		Conveyance %
					lit/sec	**li/sec/m**	
	1	350	250	208.7	11.30	0.032	83.48
Field I	2	350	245	212.6	12.40	0.035	86.78
	3	350	241	199.8	15.20	0.043	82.90
Average					**12.97**	**0.04**	**84.39**
	1	420	175	132.3	12.70	0.030	75.60
Field II	2	420	169	125.61	11.39	0.027	74.33
	3	420	176	124	12.00	0.029	70.45
Average					**12.03**	**0.03**	**73.46**
	1	320	89	67	15.00	0.047	75.28
Field III	2	320	84	72	12.00	0.038	85.71
	3	320	83	70.69	7.31	0.023	85.17
Average					**11.44**	**0.04**	**82.05**

Depending on the condition of the infrastructure, the length of the canals and the climate, water delivery along canal system; percolation into the ground, seepage through the canal bunds, spilling over the bunds and through holes in the bunds, uptake by tidies on the bunds or banks and evaporation from the water surface. The losses can estimate and measured to assess the conveyance efficiency (Ec) in percent. According to FAO (1989), those conveyances efficiencies range between 60 - 90 %. Water delivery capacity ratio is the amount of water that crop water requirement or to give an indication of the degree to which irrigation canal is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands.

According to Garg (2015), the current channel alignment attempt to made straight as far as possible. But most of the curve become inescapable, while alignment of unlined channels should be gentle as possible. Also irrigation schedule manual 4 the conveyance efficiency classified interims of soil class 80% on sandy, soil, 85% on loam soil and on clay 90% best conveyance, depending upon this tabulated result less efficient conveyance system were observed.

Figure 4.4 Canal water loss occurs at Gusha Elasa

4.6.1. Water delivery capacity ratio (WDC)

The WDC ratio was calculated by dividing the measured mean canal discharge at the inlet main canal head to scheme peak irrigation demand for the cropping season using equation 3.20, as mentioned under section 3.3.7, the WDC ratio value obtained was 1.22. According to Molden et al., (1998), the obtained value indicates that the system capacity is not a constraint to crop water demands.

4.6.2. Relative water supply and relative irrigation supply

Relative water supply (RWS) and relative irrigation supply (RIS) were computed using equation 3.17 and 3.18 respectively, as described in section 3.3.10. From the computation of the mean irrigation water discharge at the main canal inlet, total precipitation and crop water requirement during irrigation season (October to April) the relative water supply result obtained was 2.24. According to Molden et al., (1998), the computed RWS value indicates that the irrigation supply system has an adequate supply relative to the demand. Relative irrigation supply focuses on supply of irrigation water alone, in contrast to RWS which, also includes rainfall. The computed relative irrigation supply result during irrigation period was 2.15.

4.7. Depletion and depth of irrigation water applied

4.7.1. Soil moisture depletion (SMD)

The SMD for the eight test plots were computed using equation 3.6, as described in section 3.2.3.3. The summarized SMD values for the three field locations (upstream, middle stream and downstream) and three growth stages are presented in Table 4.7. As shows on Table 4.8 much moisture was depleted from the upper 30 cm soil depth. On average, the depth of moisture depleted for three field locations were 90.17 mm/m, 97.13 mm/m and 96.93mm/m for upstream, middle and downstream fields, respectively. For the second 30 cm depth, it was observed as 60.33mm/m, 71.77 mm/m and 49.33 mm/m, for upstream, middle and downstream fields, respectively. Here, the depletion level within 0-30cm soil depth might be due to evaporation rate as compared to much water storage within 30 - 60cm soil depth. The moisture depletion fraction of the three locations and depletion fraction of FAO recommended for three growing stages were

Table 4.7 Actual soil moisture depletion at the time of irrigation (mm/m) Gusha Elasa

	Field location in the scheme					
Stage	U/S		M/S		D/S	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	96.20	65.00	93.55	82.30	103.80	62.00
Development	91.11	34.80	97.30	41.20	98.60	49.80
Mid-season	83.20	81.20	93.54	91.80	88.40	36.20
Average	**90.17**	**60.33**	**97.13**	**71.77**	**96.93**	**49.33**

computed using equation 3.6 and presented. The actual soil moisture depletion fraction of the three fields (upstream, middle and downstream) were observed as 0.61, 0.62 and 0.65 during the initial stage; 0.64, 0.56 and 0.61 at crop development stage; and 0.47, 0.51 and 0.50 at mid-season stage for up, middle and downstream fields, respectively.

4.7.2. Depth of water application

The summarized and detail result obtained are presented in Table 4.8. The total amount of water applied to each fields were 582.29mm, 466.17mm and 383.91mm in upstream, middle and downstream locations respectively. The middle and downstream location irrigators were found to irrigate below the optimum value obtained from the program. The average water application depth for selected farmers' fields per irrigation event were 52.94mm, 51.80mm and 54.84mm for the upstream, middle and downstream fields, respectively. Average water application depth variation was observed among irrigators of the three locations due to variation in irrigation intervals and depth of application per irrigation within the scheme. The upstream field was being irrigated more frequently than middle and downstream stream fields. The irrigation interval in the scheme was decided on revolving basis by the Water Users Association, not strictly according to the crop water requirement. The observed interval of applying irrigation water for potato in the scheme for selected plots varied from 13 to 27 days for upstream to downstream location respectively in the different association. During the study, it was observed that, there was a high conflict for irrigation water during the full growing period (after sowing and mid-season). At this time, even if the WUA of the scheme had a decision for management and administration, there was a high demand for irrigation water and great conflict of interest among irrigators and specially enforced downstream location irrigators not to irrigate their land.

Table 4.8 Average depth of irrigation water applied during growing season

Field location	Time taken (Min)	length (m)	Respecting (Q l/sec)	Area m^2	Total volume(m^3)	Application depth (mm)	Irrigation . Event
U/S	295	50	1.90	635	33.63	52.94	11
M/S	290	45	2.10	705	36.54	51.80	9
D/S	230	55	1.85	466	25.53	54.84	7

4.7.3. Actual soil moisture storage

The actual moisture stored in the soil after irrigation was computed from the moisture content in volume percent basis before and after irrigation application using equation (3.6) and presented in Table 4.9. The average soil moisture stored in the upper 0-30 cm soil depth were obtained as 90.9 mm/m, 94.6 mm/m and 94.8 mm/m, for upstream, middle and downstream locations, respectively for potato crop. The results showed that much of the water applied stored in the upper 30 cm soil depth at the three growth stages (Table 4.9).

Table 4.9 Soil moisture content before and two days after irrigation Gusha Elasa

	Field location in the scheme						
Stage	SM (vol%)	U/S		M/S		D/S	
		0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	θBI	36.2	34.2	35.3	38.25	41.45	37.99
	θAI	44.5	41.8	45	45.89	46.8	44.66
Development	θBI	35.45	39	36.1	42.65	37.58	40.21
	θAI	44.8	40.8	45.8	46.53	46.95	45.2
Mid-season	θBI	38.2	34.2	41	37.64	36.55	39.75
	θAI	45.55	41.65	46	46.76	44.75	43.22

The actual moisture stored (AMS) in the soil which was evaluated two days after irrigation shows that the average depth of water stored was nearly equal to the depth of water required to restock the water depleted from the root zone prior to irrigation, except for downstream irrigators (Table 4.10). However, the depth water was less than the depth of water depleted from the root

Table 4.10 Actual soil moisture depletion and storage in the root zone (mm)

Stage	U/S		M/S		D/S	
	SMD (mm)	AMS (mm)	SMD (mm)	AMS (mm)	SMD (mm)	AMS (mm)
Initial	18.92	19.2	20.55	20.4	23.44	19.75
deve.pt	31.62	29.66	31.43	32.6	30.08	31.3
Mid-season	49.39	50.53	54.6	58.8	49.64	37.7
Average	**33.31**	**33.13**	**35.53**	**37.3**	**34.39**	**29.58**

zone earlier to irrigation at initial growth stage (for middle and downstream), development stage (for upstream) and mid-season (for upstream, middle and downstream) field location. The result also indicates that most of the time the irrigators applied water to their fields nearly at field capacity.

4.8. Performance indicators evaluation

4.8.1. Application efficiency

Water application efficiency provides a general indication of how healthy irrigation system can performs its principal task of delivering water from the conveyance system to the crop cultivated command area. Table 4.11 presents summary of application efficiency (Ea) obtained using equation (3.14) as described in Section 3.3.6 for test plots of the three field locations (upstream, middle stream and downstream). The obtained average values were 49.05%, 54.37% and 59.4% for upstream, middle stream and downstream users respectively.

Table 4.11 Application efficiency for three field location test plots Gusha Elasa

	Field location in the scheme								
Location	U/S			M/S			D/S		
Stage	WAD (mm)	AMS (mm)	Ea%	WAD (mm)	AMS (mm)	Ea%	WAD (mm)	AMS (mm)	Ea%
Initial	76.62	19.2	36.75	63.2	20.4	32.4	59.95	19.75	39.3
Devel.	70.38	29.66	45.85	50.78	32.6	67.5	41.6	31.3	73.65
Mid	85.34	50.53	64.55	75.8	58.8	73.3	55.95	37.7	61.25
Average			49.05			54.4			59.4

According to, Walker (1998) the recommended value for application efficiency of surface irrigation are 50- 60% is good, 30-40% is reasonable and 20-30% poor. Therefore, the result obtained for the application efficiency not satisfactory. Water losses on-farm or on the field are caused by deep percolation to soil layers below the crop root zone, by surface run-off, by use of weeds and by evaporation from the soil surface between the crops. The field application efficiency mainly depends on the irrigation method and level of farmer discipline. According to FAO (1989), some indicative values of the average field application efficiency for surface irrigation furrow efficiency 60%.

4.8.2. Storage efficiency

Storage efficiency to determine the amount of water that, stored in the root zone during irrigation. The storage efficiencies was computed by monitoring soil moisture before and after irrigations (Refer equation (3.13) as described in Section 3.3.5 and results are shown in Table 4.12. The average results of storage efficiency gained were 89.73%, 90.9% and 88.33% for upstream, middle and downstream locations of the test plots respectively. According to Raghuwanshi and Wallender (1998), the suggested storage efficiency is 87.5%. Thus, the storage efficiency of the scheme indicated that the irrigation system was adequate in fulfilling the soil moisture required for good productivity of the crops.

Table 4.12 Storage efficiency Gusha Ejersa

Field location in the scheme									
Stage	U/S			M/S			D/S		
	SMD (mm)	AMS (mm)	Es %	SMD (mm)	AMS (mm)	Es%	SMD (mm)	AMS (mm)	Es %
Initial	18.92	19.2	89.5	20.55	20.40	91.5	23.44	19.75	87.2
deve.pt	31.62	29.66	92.1	31.43	32.60	92.8	30.08	31.3	89.6
Middle	49.39	50.53	87.6	54.60	58.80	88.4	49.64	37.7	88.2
Average	33.31	33.13	89.73	35.53	37.3	90.9	34.39	29.58	88.33

4.8.3. Distribution uniformity

Distribution uniformity is used to express the variation in depths of application or volume of water supplied to be command area. Distribution uniformity of the scheme was evaluated by monitoring the depth of water infiltrated into the root zone depth using soil moisture content in equation (3.15) of Section (3.3.7) and presented in (Table 4.13). The average results obtained were 89.12%, 87.22% and 87.94% for upstream, middle and downstream locations of the test plots respectively. From the results observed, there was a small difference of uniformity within three locations of the test plots. According to FAO (1989), all the results obtained are within acceptable range (greater than 80%). FAO (1992) also suggested that in an average rotational supply with adequate management and communication, having distribution uniformity of 65% as “sufficient” and DU of 30% as “poor”. Thus, the average values of DU of the scheme indicate the distribution uniformity of irrigation water in the selected farmers' field was sufficient.

Table 4.13 Distribution uniformity Gusha Ejersa (%)

Field location in the scheme						
Stage	U/S		M/S		D/S	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	91.20	87.4	85.9	87.5	86.8	85.7
development	88.10	91.11	89.3	88.4	88.9	89.1
Mid-season	90.2	86.7	89.8	82.4	90.5	86.6
Average	**89.12**		**87.22**		**87.93**	

4.8.4. Christiansen uniformity coefficient

The Christiansen's uniformity coefficient was obtained using equation (3.16) of section 3.3.8. The obtained results were 89.59%, 87.79% and 89.21% for upstream, middle and downstream fields of the scheme respectively (Table 4.14). The reason for achieving higher values of CUC in this study might be due to the flatness of the test plot fields and uniformity (clay nature) of soil texture.

Table 4.14 Christiansen uniformity coefficient Gusha Ejersa %

	Field location in the scheme					
Stage	U/S		M/S		D/S	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	92.37	89.37	85.51	87.42	89.76	88.15
Development	86.84	91.11	89.3	88.4	86.95	89.09
Mid-season	89.06	88.78	87.27	88.82	90.53	90.8
Average	**89.59**		**87.79**		**89.21**	

4.8.5. Deep percolation ratio

Since the irrigation scheme considered in this study is blocked end furrows, the main source of water loss was deep percolation. The deep percolation ratio calculated using equation (3.19) was 50.95%, 42.97 % and 42.60 % for upstream, middle stream and downstream test plots, respectively in Table 4.15. As result, the high deep percolation ratio was observed at the upstream and low at the downstream location of the test plot; it indicates that losses are in decreasing trend as the access of getting water are decreasing or downstream irrigators are irrigating with minimum loss as compared to upstream and middle irrigators. From the result obtained a higher deep percolation ratio was observed in lower application efficiency. During the study period it was observed that some irrigators in the upstream parts of the scheme were trying to drain out excess water from their fields due to the command farm slope in Table 4.15 presents summary of the results of field efficiency indices obtained for test plots (upstream, middle stream and downstream). Water in to the field plot in upper stream than middle and downstream field of location. As resulted from the CRPOWAT 8.0 program the interval of water application and it was observed a great deference on site, this is a factor for reduction of expected yield output in traditional way of application from 13 to 27 days of irrigation interval. In addition to this, the members of water users association also affect the irrigation intensity. This losses may vary from 20% to 50% of the water to be diverted in to channel at head work. So, depending upon table 4.18 the amount of water losses can be accounted by percolation and absorption increases relative to soil type and depth of channel. output in traditional way of application from 13 to 27 days of irrigation interval. In addition to this, the members of water users association also affect the irrigation intensity. Losses of water vary from 20% to 50% of the water to be diverted in to channel at head work. So, depending upon table 4.18 the amount of water losses can be accounted by percolation and absorption increases relative to soil type and depth of canal.

Table 4.15 Summary of field efficiencies and losses for Gusha Ejersa

		Efficiencies				Losses
location	Stage	Ea (%)	Es (%)	DU (%)	CUC (%)	DPR (%)
U/S	Initial	36.75	89.50	89.30	90.87	63.25
	Development	45.85	92.10	89.61	88.98	54.15
	Mid-season	64.55	87.60	88.45	88.92	35.45
	Average	49.05	89.73	89.12	89.59	50.95
M/S	Initial	34.35	91.50	86.70	86.47	65.65
	Development	67.50	92.80	88.85	86.47	32.50
	Mid-season	78.25	88.40	86.10	86.47	21.75
	Average	60.03	90.90	87.22	86.47	39.97
D/S	Initial	38.30	87.20	86.25	88.96	61.70
	Development	73.65	89.60	89.00	88.96	26.35
	Mid-season	60.25	88.20	88.55	88.96	39.75
	Average	57.40	88.33	87.93	88.96	42.60

4.9. Water use efficiency

4.9.1. Crop water requirement

Crop water requirement calculated the amount of water to be applied during crop period, this determine using equation (3.20) and presented in Table 4.16. The obtained result was 2.16 kg/m^3, 3.07 kg/m^3 and 1.80 kg/m^3 for upstream, middle stream and downstream location of the test plots, respectively. Here, the productivity for the farmer's field located at middle stream of the scheme had the highest return per unit of water consumed 3.07kg/m^3. This might be due to the total depths of water applied (329.91mm) in full growing season which was nearest to crop water requirement as calculated by the CROPWAT 8.0 software program value (329.91 mm/season). The potato yield obtained from head, middle and tail end test plots were 7.11, 10.13 and 5.93 tons/ha respectively, with the average of 7.72 tons/ha. The obtained result was higher than the value indicated by Getachew et al. (2009) which is 6 tons/ha under farmer's condition.

Table 4.16 Water productivity in terms of water consumed by crop for Gusha Ejersa

Field location	Area (ha)	ETc (mm/ season)	Water consumed (m^3/ha)	Potato product (Kg/ha)	PWA Kg/ha)	WPRC (Kg/m^3)
U/S	0.0456	304.50	3,045.00	368.40	8,078.95	2.65
M/S	0.0368	329.91	3,299.10	335.00	9,103.26	2.76
D/S	0.0485	355.60	3,556.00	342.80	7,068.04	1.99

Note: PWRC is water productivity in terms of water requirement by crop.

4.9.2. Water productivity (WP)

The water productivity in terms of the crop water applied was estimated using equation (3.15) and presented in Table 4.17. The obtained result shows that the productivity in terms of yield per unit volume of water applied was 1.141 kg/m^3, 1.279kg/m^3 and 1.201kg/m^3 for upstream, middle and downstream fields, respectively. The economic water productivity in terms of monetary units was calculated using equation (3.21). Gross monetary returns in birr were 25.01Birr/m^3, 34.76Birr/m^3 and 24.76Birr/m^3 for upstream, middle and downstream fields, respectively. The total depths of water applied per season were in the order of 708.30 mm, 690.40mm and 588.60mm for upstream, middle stream and downstream irrigators, respectively.

Table 4.17 Production per unit water applied for Gusha Ejersa

Field location	Area (ha)	WA(mm)	WA (m^3/ha)	Potato wt (Kg)	Potato wt (Kg/ha)	WPA Kg/m^3)	WPE (Birr/m^3)
U/S	0.0456	708.3	7,083.00	368.4	8,078.95	1.141	25.01
M/S	0.0368	690.4	6,904.00	325	8,831.52	1.279	34.76
D/S	0.0485	588.6	5,886.00	342.8	7,068.04	1.201	24.76

Note: WPA is water productivity in terms of water applied;

WPE is water productively economic in terms of monitory units;

It was also observed that the upstream and the downstream irrigators applied more and less amount of water respectively than the crop water requirement calculated by the CROPWAT 8.0 software (664.50 mm/season).

4.10. Irrigation water analysis

From the economic point of view, the economic efficiency of the project was evaluated by comparing the benefits gained from the potato yield with the total cost of production as described in section 3.6 (Refer Equation (3.22) and Equation (3.23)). The expected production quantity and costs of production for potato and other cultivated market crops during the study period were collected from the irrigators in the upstream, middle and downstream of the plot level. The expected production and their market value of each crops analyzed for applied water and condensed potato production in 2016 are tabulated in Table 4.18.

Farmers in the middle fields applied water nearly equal to the water requirement of the crop as calculated by CROPWAT software program. In general, the analysis indicates that potato production in the scheme is economically efficient in terms of water use, since the benefit income values of the three locations were good. As Table 4.17 we observed that, amount of water that applied to the cultivated land more efficient relative to the middle and downstream fields due to good soil moisture content and it estimated with water cost fee. While the middle cultivated land have consumed water, because of two reasons, they use illegally at night time to diverted water to plot and most of water waste as drain and at intermediate site additional water source so, their water application inefficient and it estimated with water cost fee in appropriate manner. In the downstream there efficiency lay between upper and downstream. So, water cost per plot 1.81, 2.45, and 2.09 in upstream, middle, and downstream plot respectively.

Table 4.18 Irrigation water analysis for Gusha Ejersa

Field location	Area (ha)	VWA(m3/ season)	VWA (m3/ ha/season)	Cost of Water (Birr/1000m3)	TWC Birr/ plot/season)	TWC (Birr/ ha/season)
U/S	0.0456	478.40	5,783.00	6.00	1.81	39.78
M/S	0.0368	459.60	5,104.00	6.00	2.45	66.49
D/S	0.0485	494.80	4,886.00	6.00	2.09	43.05

Note; AWA: Amount of water applied; WAC: water applied Cost.

4.11. Water use performance

During the field observation the result it observed from different fields by examination internal and external indicators to analyze the result reasonable to the other source of result stated.

Crop production

According to FAO Rome (2002), the amount of water consumed by potato was depleted by 20 percent in the form of water depletion; this can affect the expected agrarian's crop production. In all the Degaluna Tijo Wareda, the main productive potato and shallot grown vary based on altitude of the schemes. From the indicators, comparing the performance of irrigation system of IWMI reported paper 20 (1998) the result obtained that the economic value of each crop were partially good result regarding to the result that we obtained. This indicates that in Ethiopia irrigation practice starts early century, but the result we obtained as water cost value and economic development not gained the value we invest. Therefore, the overall performance of traditional schemes, including crop productivity and the efficiency of water use, are generally low.

Seepage and sedimentation

As given to reduce the amount water seepage and deeper collation could be made to describe the assessment of these farmers over how to function and maintain and how to applied water to increase the performance of irrigation scheme. For instance, they appeared to have specific problems on the operation and maintenance of the canal network, which in comparison to the perception of farmers from Gesha Elasa appears to the main constraint for the normal advance of irrigation. Also sedimentation load are affect the performance of traditional one and as compared with modern irrigation scheme due to not have mechanism of sediment controlling.

4.12. Institutional support

During field observation farmers respond that, Woreda's had not support well as we expected to improve crop production. In addition to this the responsible body to support some technical water management, as a result a period of pick crop water requirement conflict may began between them. If Woredas overall responsibility is to equip the farmers with modern technical know-how and improved methods of farming to increase agricultural productivity and farm income level.

- The executive body responsible for all aspects of the water sector including expansion of irrigated areas, water conservation, surface and groundwater use, and river management.
- To promote the development of irrigation based on strategic planning for achieving socioeconomic goals and a participatory approach for promoting efficiency and sustainability.
- Providing administrative, technical and legal support farmers.
- To develop a demand of schemes on the basis of achieving food self-sufficiency and production of industrial farmers.
- To support and modernize traditional irrigation system by providing inputs that would improve their efficiency.
- To protect and maintain acceptable water quality standards for crop water requirement.
- To develop water user allocation and priority setting criteria between upstream and downstream user to reduce water conflict.

CHAPTER FIVE

5. Conclusions and Recommendations

5.1. Conclusions

From this research the following conclusions can be outlined.

The main water conveyance and distribution canal of the study area was under a serious pressure point of water resource value sense and become failure because of the destruction of the both side of canal bank and nonexistence of aqueduct by the rapidly advancing river bank. The irrigation water application at farmers' field level in the scheme at the upstream location was not good. Low irrigation efficiencies were achieved because applications far exceed farmers' management not knows how to apply. Due to over irrigation of water for extensive period in the upstream fields of the scheme, water logging problem was observed. On the other hand, downstream irrigators' crops were suffered from shortage of water.

The average application efficiency obtained were 49.05%, 59.37% and 57.40% for upstream, middle and downstream fields respectively. The average storage efficiency, it calculated from moisture contents for three locations were found as 89.12%, 87.22% and 87.94% for upstream, middle and downstream fields, respectively. While, the distribution uniformity was found as 89.27%, 88.28% and 89.21% for upstream, middle and downstream fields, respectively. Christiansen uniformity coefficient obtained from the same moisture content was observed as 89.59%, 86.47% and 88.96% for upstream, middle and downstream test plots respectively. Since the system used in the area was close end furrow irrigation, no runoff was observed. The only source of losses was deep percolation, which was found to be 50.95%, 42.97% and 42.60% for upstream, middle and downstream, respectively. This indicates that the upstream location irrigators are least efficient than downstream. The crop and irrigation water requirement of the selected major crops was calculated using the CROPWAT 8.0 software program. From the computation of the CROPWAT model the seasonal water requirements of potato and shallot was 352.00mm and effective rainfall was 112.80 mm.

After determining the amount of water applied per season and estimating amount of water consumed by crop, the water productivity in terms of water use efficiency was computed. The potato yield obtained from upstream, middle and downstream fields were 7.31, 10.26, and 8.13 tons/ha, respectively. The amounts of water applied were 708.30mm, 690.40mm, and 588.60mm, respectively. The corresponding water productivity in terms of volume of water applied were

$1.22 kg/m^3$, $1.71 kg/m^3$, and $1.35\ kg/m^3$. Economic value of water use efficiency was obtained water value and found as 2.27,2.34 and 1.77 for head, middle and tail end location of the scheme, respectively.

Illegal water abstraction method and unequal water distribution were considered to be a serious problem and needs immediate attention. There is a room to improve performance of furrow irrigation system in the scheme through selection of appropriate flow rate and time of cutoff that would result in maximum or near maximum application and acceptable level of deep percolation loss, while applying a depth equivalent to the management allowable soil moisture deficit to bring back the soil to the field capacity.

In general, from the results of water productivity obtained, it can be concluded that productivity of the cropping system can be improved by minimizing water losses due to over irrigation of the root zone and applying water according to water requirement.

5.2. Recommendations

From the study, the following recommendations are forwarded as sustainable for the wise use water resource operation will be:-

For efficient use and impartiality distribution of irrigation water within and among farmers at different locations from upper stream and downstream, and at the same time to avoid water logging problem along the canal and at field due to poor water management, it is improved to give concentrated practical or theoretical training to the farmers how to assess the water application farming system and economical application of water at the field which in turn results in upgrading the yield of crops as well as to decline water logging along the canal and field.

As the absence of appropriate or good water diversion head work and alignment of canal layout, water controlling mechanism where contributed to inequality of water distribution among farmers and for efficient canal conveyance. To advance field application efficiency and overall water productivity of the scheme, farmers should apply irrigation earlier or on time crop water required. When the readily available soil water is depleted and avoid over irrigation (deep percolation losses that may leach relevant nutrients out of the crop root zone), by applying irrigation to the depth smaller than or equal to the root zone depletion.

Any part of supervision from the governmental body, which belongs to assess irrigation, should give attention on guidance and support of farmers in developing and introduction of appropriate depth of irrigation, interval irrigation intensity, in addition to improving canal passageway of the scheme for future use. For good practice Woreda's water and irrigation authority office can be support these irrigation association, group and community for better water use and good production within wise use of our resource as well as to reduce conflict between upstream and downstream water user.

Overtopping causes erosion of the canal banks and may lead to serious large trees root and mouse holes. It can be avoided by improving the operation of the system. Discharges should be limited and water controlling system should be needed to closed and opened the applied water according to the crop water requirement planned schedule.

The environmental impact continue within this sequences there is series damage may be happen in the future because of deferent aspect, those aspect where increasing population growth and this resulted to deforestation the oldest (environmentally indigenous growing trees) forest land.

This can a series affect behind Woreda's as well as water shade; which may know within different resource to be loss without understanding.

The result we observe from remote sensing image that land use land cover change before two decade the forest area rapidly become insignificant, so the Woreda Agricultural Agency have been ended their responsibility ways to manage those indigoes forest become rehabilitation to sustain the pervious hydrological, ecological and climatologically condition of study area.

Conflicts concerning irrigation water depend on a number of reasons such as water scarcity, unfair water allocation and distribution, population growth and livestock. One common problem is the tension between upstream and downstream stakeholders because of their different strategic positions.

Training in water management, marketing and general crop production is important for irrigation scheme association. The economics of small-scale irrigation in the study Woreda is not well understood. Farther economic evaluation of optimal plot size, cropping patterns, technologies, agronomic practices and resources utilized in the irrigation schemes is necessary Empowerment of local communities should be given due consideration since they are playing major role in irrigation development in the water shade.

Since the participant of women in the economic development in the as country level were one of the important component and key to accelerate the economic value but, during my study and data collection time from the all irrigation associations only one irrigation association have women's member and it production result good. As a result the Woreda's have to do the experience or knowledge share between those association to change their attitude.

Generally we recommended that which select for this study area have great coincidental for twice annual cultivation cash crop and food crops by irrigated system or wet season, but currently this become inverse of the previous occurrence as early discussed change environmental climate condition affect all the traditional irrigation scheme or system that peoples work progresses for better life. So if that environmental cannot be rehabilitation within their character the draught which began to attack may continue without boundless mark this economical declination where influences.

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Appendix

Table 1 Attachment of soil laboratory test result

Company Name: በኢትዮጵያ የኮንስትራክሽን ዲዛይንና ሱፐርቪዥን ስራዎች ኮርፖሬሽን
ምርምር፣ላቦራቶሪና ስልጠና ማዕከል
Ethiopian Constraction Design & Supervision Works Corporation
Research,Laboratory and Traning Center

Soil Fertility & Plant Section — ***የአፈር ለምነት እና የዕጽዋት ክፍል***

Tel. 251 - 116 - 61 45 01, 251 - 116 - 61 01 05 | Fax. 251 - 116 - 61 53 71/61 08 98 | e-mail w.w.d.s.e@ethionet.et | P.O.Box 2561 | Addis Ababa Ethiopia

Client:- Institute of Technology Hawassa University

Laboratory Number	672/09	673/09	674/09	675/09	676/09	Test Method
PROFILE CODE	Gusha Brun	Gusha Brun	Gush Borona Sample 2	Gush Borona Sample 2	Gush Braro Borshe Sample 3	
DEPTH (cm)	at 20	at 40	at 20	at 40	at 20	
Received Date	06/01/17	06/01/17	06/01/17	06/01/17	06/01/17	
Sand (%)	80.96	37.36	23.73	34.44	29.00	Hydrometer
Clay (%)	2.12	25.92	40.25	29.61	39.68	
Silt (%)	16.93	36.72	36.02	35.95	31.32	
Texture Class	Sandy Loam	Loam	clay	Clay loam	Clay loam	
P^{H}-H_2O (1:2.5)	5.36	5.56	5.40	5.52	5.46	Probe method
Organic Carbon(%)	6.19	4.98	3.99	5.55	4.13	Walklay Black
Organic Matter(%)	10.67	8.58	6.88	9.57	7.12	
Field Capacity (%) (0.33bar)	38.85	35.29	33.85	36.01	29.74	Gravimetric
Permanent Wilting Point(%) (15 bar)	18.23	19.50	20.25	20.83	18.18	

Remark:

Processed by ____ Date 02/02/2017   Checked by ____ Date 02/02/2017   Approved By ____ Date 02/02/2017

Table 2 Attachment of soil laboratory test result

Company Name: በኢትዮጵያ የኮንስትራክሽን ዲዛይንና ሱፐርቪዥን ስራዎች ኮርፖሬሽን
ምርምር፣ላቦራቶሪና ስልጠና ማዕከል
Ethiopian Constraction Design & Supervision Works Corporation
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Soil Fertility & Plant Section — የአፈር ለምነት እና የዕጽዋት ክፍል

Tel. 251 - 116 - 61 45 01, 251 - 116 - 61 01 05 Fax. 251 - 116 - 61 53 71/61 08 98 e-mail w.w.d.s.e@ethionet.et P.O.Box 2561 Addis Ababa Ethiopia

Client:- Institute of Technology Hawassa University

Laboratory Number	682/09	683/09	684/09	685/09	Test Method
PROFILE CODE	Gumechu Sample 2	Gumechu	Shenkola Sample 1	Shenkola Sample 1	
DEPTH (cm)	at 20	at 40	at 20	at 40	
Received Date	06/01/17	06/01/17	06/01/17	06/01/17	
Sand (%)	34.13	15.90	28.26	23.73	Hydrometer
Clay (%)	27.62	56.77	40.09	44.49	
Silt (%)	38.25	27.33	31.65	31.78	
Texture Class	Clay loam	clay	clay	clay	
P^H-H_2O (1:2.5)	5.70	5.74	5.16	5.24	Probe method
Organic Carbon(%)	5.32	1.45	5.02	3.95	Walklay Black
Organic Matter(%)	9.17	2.49	8.65	6.82	
Field Capacity (%) (0.33bar)	34.95	29.71	33.88	29.76	Gravimetric
Permanent Wilting Point (%) (15 bar)	18.81	18.73	25.70	18.83	

Remark:

Processed by Date 02/02/2017

Checked by Date 02/02/2017

Approved By Date 02/02/2017

Table 3 Attachment of soil laboratory test result

Company Name:

በኢትዮጵያ የኮንስትራክሽን ዲዛይንና ሱፐርቪዥን ስራዎች ኮርፖሬሽን
ምርምር፣ላቦራቶሪና ስልጠና ማዕከል

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Soil Fertility & Plant Section ***የአፈር ለምነት እና የዕጽዋት ክፍል***

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251 - 116 - 61 01 05 e-mail w.w.d.s.e@ethionet.et Ethiopia

Client:- Institute of Technology Hawassa University

Laboratory Number	677/09	678/09	679/09	680/09	681/09	Test Method
PROFILE CODE	Gush Braro Borshe Sample 3	Gusha Tana	Gusha Tana	Gole Elan3037 m	Gole Elan3037 m	
DEPTH (cm)	at 40	at 20	at 40	at 20	at 40	
Received Date	06/01/17	06/01/17	06/01/17	06/01/17	06/01/17	
Sand (%)	17.37	27.53	15.83	23.32	16.73	Hydrometer
Clay (%)	61.44	54.90	70.88	51.12	59.78	
Silt (%)	21.19	17.57	13.29	25.56	23.49	
Texture Class	clay	clay	clay	clay	clay	
p^H-H_2O (1:2.5)	5.86	5.57	5.88	5.44	5.38	Probe method
Organic Carbon(%)	3.14	3.56	1.02	4.05	1.98	Walklay Black
Organic Matter(%)	5.42	6.13	1.76	6.98	3.42	
Field Capacity (%) (0.33bar)	35.36	34.40	39.19	34.35	32.76	Gravimetric
Permanent Wilting Point (%) (15 bar)	19.90	24.19	33.37	20.50	21.44	

Remark:

Processed by ______ Date 02/02/2017 Checked by ______ Date 02/02/2017 Approved By ______ Date 02/02/2017

Table 4 Actual soil moisture depletion at the time of irrigation (mm/m)

	Temela						**Gusha Ejersa**					
	Field location in the scheme						Field location in the scheme					
Stage	U/S		M/S		D/S		U/S		M/S		D/S	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	89.17	63.21	84.31	76.42	78.09	55.84	84.83	63.81	76.36	75.34	95.19	54.19
Development	78.20	31.21	96.24	32.18	98.41	39.78	73.63	32.94	84.69	35.58	85.68	42.43
Mid-season	79.49	62.43	80.11	74.75	87.54	29.13	81.4	78.82	83.52	84.19	78	31.67
Average	**82.29**	**52.29**	**86.89**	**61.12**	**88.01**	**41.58**	**79.95**	**58.52**	**81.52**	**65.04**	**86.29**	**42.76**
		Shaaldo						**Degalu bora**				
Stage	U/S		M/S		D/S		U/S		M/S		D/S	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	83.3	58.59	75.06	72.77	102.81	54.23	73.28	50.16	89.38	67.88	92.98	57.71
Development	70.74	28.72	84.05	33.26	81.98	48.46	79.2	30.51	80.28	31.17	92.67	42.58
Mid-season	70.83	73.1	92.77	78.39	82.04	32.1	66.78	68.4	79.65	74.79	70.57	28.3
Average	**74.96**	**53.47**	**83.96**	**61.47**	**88.94**	**44.93**	**73.08**	**49.69**	**83.1**	**57.95**	**85.41**	**42.86**
		Hobori						**Yeguga**				
Stage	U/S		M/S		D/S		U/S		M/S		D/S	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	74.69	53.64	80.81	66.44	86.3	60.33	83.73	56.13	81.29	70.12	87.45	51.65
Development	77.57	31.33	96.5	35.18	91.51	44.16	81.35	31.91	85.85	36.04	84.7	41.99
Mid-season	76.48	71.23	87.12	86.28	80.31	31.62	79.49	66.98	83.79	85.45	84.84	35.79
Average	**76.25**	**52.07**	**88.15**	**62.63**	**86.04**	**45.37**	**81.52**	**51.67**	**83.64**	**63.87**	**85.66**	**43.14**

Table 5 Summary of field efficiencies and waater losses

		Temela					**Gusha Elasa**				
		Efficiencies				Losses	Efficiencies				Losses
Test location	Stage	Ea (%)	Es (%)	DU (%)	CUC (%)	DPR (%)	Ea (%)	Es (%)	DU (%)	CUC (%)	DPR (%)
U/S	Initial	35.56	67.28	77.32	82.84	64.44	33.61	89.42	76.62	78.67	66.39
	Development	41.54	85.37	79.76	76.98	58.46	42.33	78.68	81.93	79.25	57.67
	Mid-season	60.54	75.19	69.17	79.02	39.46	57.89	85.63	84.10	69.56	42.11
	Average	45.88	75.95	75.41	79.61	54.12	44.61	84.58	80.88	75.82	55.39
M/S	Initial	33.13	80.13	83.89	68.81	66.87	32.54	82.48	80.64	83.66	67.46
	Development	60.34	86.17	80.93	85.98	39.66	66.67	76.58	84.46	80.93	33.33
	Mid-season	66.54	69.04	71.46	80.17	33.46	72.97	79.59	74.48	72.96	27.03
	Average	53.34	78.45	78.76	78.32	46.66	57.39	79.55	79.86	79.18	42.61
D/S	Initial	34.58	74.18	80.49	66.92	65.42	37.76	32.94	86.61	83.02	62.24
	Development	64.80	86.17	72.69	82.13	35.20	77.75	75.24	81.53	71.87	22.25
	Mid-season	62.92	85.98	70.19	74.05	37.08	65.80	67.38	68.26	71.83	34.20
	Average	54.10	82.11	74.46	74.37	45.90	60.44	58.52	78.80	75.57	39.56
		Shaaldo					**Deg. bora**				
		Efficiencies				Losses	Efficiencies				Losses
Test location	Stage	Ea (%)	Es (%)	DU (%)	CUC (%)	DPR (%)	Ea (%)	Es (%)	DU (%)	CUC (%)	DPR (%)
U/S	Initial	34.88	68.17	69.84	75.78	65.12	33.82	76.82	76.07	86.40	66.18
	Development	43.62	80.06	83.68	76.98	56.38	41.96	87.99	80.02	73.24	58.04
	Mid-season	61.56	70.31	77.33	79.02	38.44	58.75	87.52	79.86	74.25	41.25
	Average	46.69	72.85	76.95	77.26	53.31	44.85	84.11	78.65	77.96	55.15
M/S	Initial	33.44	75.47	71.84	76.61	66.56	31.99	71.46	78.46	74.69	68.01
	Development	65.59	70.21	69.69	85.98	34.41	62.69	75.57	73.49	71.62	37.31
	Mid-season	71.19	72.02	77.90	80.17	28.81	67.99	79.69	73.24	67.93	32.01
	Average	56.74	72.57	73.14	80.92	43.26	54.22	75.57	75.06	71.41	45.78
D/S	Initial	35.04	83.69	68.34	83.87	64.96	36.44	85.00	75.68	68.54	63.56
	Development	65.32	76.61	67.95	82.13	34.68	68.39	88.38	70.43	67.99	31.61
	Mid-season	54.03	67.50	80.77	74.05	45.97	56.96	87.35	75.40	68.21	43.04
	Average	51.47	75.93	72.35	80.02	48.53	53.93	86.91	73.83	68.24	46.07
		Beriti						**Yeguga**			
		Efficiencies				Losses	Efficiencies				Losses

Test location	Stage	Ea (%)	Es (%)	DU (%)	CUC (%)	DPR (%)	Ea (%)	Es (%)	DU (%)	CUC (%)	DPR (%)
U/S	Initial	33.26	87.73	74.07	77.55	66.74	32.70	72.05	77.05	83.97	67.30
	Development	41.26	81.21	70.25	81.40	58.74	40.56	80.16	76.88	88.98	59.44
	Mid-season	57.76	70.79	80.03	84.52	42.24	56.77	78.21	75.49	88.92	43.23
	Average	44.09	79.91	74.78	81.16	55.91	43.34	76.81	76.47	87.29	56.66
M/S	Initial	32.60	32.20	68.68	65.89	67.40	33.58	79.97	69.53	86.47	66.42
	Development	64.61	64.20	67.84	84.46	35.39	66.54	71.07	75.81	88.85	33.46
	Mid-season	70.86	77.61	78.54	76.06	29.14	72.95	77.34	65.51	88.05	27.05
	Average	56.03	58.00	71.68	75.47	43.97	57.69	76.13	70.28	87.79	42.31
D/S	Initial	36.30	72.51	65.70	62.72	63.70	36.01	72.99	70.41	88.96	63.99
	Development	67.84	77.21	66.37	80.63	32.16	67.30	73.79	75.02	88.02	32.70
	Mid-season	56.27	74.31	81.36	69.84	43.73	55.82	67.10	62.45	90.67	44.18
	Average	53.47	74.68	71.14	71.06	46.53	53.04	71.29	69.29	89.21	46.96
		Hobori									
		Efficiencies				Losses					
		Ea (%)	Es (%)	DU (%)	CUC (%)	DPR (%)					
U/S	Initial	35.05	74.05	81.43	77.98	64.95					
	Development	43.82	80.16	77.53	75.92	56.18					
	Mid-season	61.84	78.21	78.48	81.21	38.16					
	Average	46.90	77.47	79.15	78.37	53.10					
M/S	Initial	33.41	79.97	69.00	73.79	66.59					
	Development	65.52	79.07	85.98	67.67	34.48					
	Mid-season	71.11	77.34	78.50	83.68	28.89					
	Average	56.68	78.79	77.83	75.05	43.32					
D/S	Initial	34.67	72.99	64.87	74.98	65.33					
	Development	64.62	73.79	83.06	62.03	35.38					
	Mid-season	53.45	72.97	72.37	83.06	46.55					
	Average	50.92	73.25	73.43	73.35	49.08					

Table 6 Main canal conveyance efficiency and water loss

Canal type	Segmen t	D/ce b/n (m)	Inflow l/se	Out flow l/s	Canal loss		Canal %	D/ce b/n \m)	Inflow l/se	Out flow l/s	canal loss		canal %
		Gusha Elasa			l/s	l/s/m			Temela		l/sec	l/s/m	
	1	300	222	126.43	95.57	0.32	56.95	350	250	208.7	41.3	0.12	83.48
Field I	2	300	215	208.49	6.51	0.02	96.97	350	245	212.6	32.4	0.09	86.78
	3	300	201	121.25	79.75	0.27	60.32	350	241	199.8	41.2	0.12	82.9
Average					**60.61**	**0.2**	**71.41**				**38.3**	**0.11**	**84.39**
	1	400	180	99.06	80.94	0.2	55.03	420	175	132.3	42.7	0.1	75.6
Field II	2	400	172	122.61	49.39	0.12	71.28	420	169	125.61	43.39	0.1	74.33
	3	400	175	128	47	0.12	73.14	420	176	124	52	0.12	70.45
Average					**59.11**	**0.15**	**66.49**				**46.03**	**0.11**	**73.46**
	1	250	91	42.19	48.81	0.2	46.37	320	89	67	22	0.07	75.28
Field III	2	250	88	68	20	0.08	77.27	320	84	72	12	0.04	85.71
	3	250	85	65	20	0.08	76.47	320	83	70.69	12.31	0.04	85.17
Average					**29.6**	**0.12**	**66.7**				**15.44**	**0.05**	**82.05**
		Hobori							Yeguga				
	1	350	236	140.58	95.42	0.27	59.57	200	250	208.7	41.3	0.21	83.48
Field I	2	350	230	141.78	88.22	0.25	61.64	200	245	212.6	32.4	0.16	86.78
	3	350	221	131.9	89.1	0.25	59.69	200	241	199.8	41.2	0.21	82.9
Average					**90.91**	**0.26**	**60.3**				**38.3**	**0.19**	**84.39**
	1	420	178	124.11	53.89	0.13	69.72	250	175	132.3	42.7	0.17	75.6
Field II	2	420	170	80.4	89.6	0.21	47.29	250	169	125.61	43.39	0.17	74.33
	3	420	170	78.53	91.47	0.22	46.2	250	176	124	52	0.21	70.45
Average					**78.32**	**0.19**	**54.4**				**46.03**	**0.18**	**73.46**
	1	320	94	55.87	38.13	0.12	59.43	300	89	67	22	0.07	75.28
Field III	2	320	84	60.97	23.03	0.07	72.59	300	84	72	12	0.04	85.71
	3	320	87	60.79	26.21	0.08	69.87	300	83	70.69	12.31	0.04	85.17
Average					**29.12**	**0.09**	**67.3**				**15.44**	**0.05**	**82.05**
		Arabi							Beriti				
	1	300	250	111.93	138.07	0.46	44.77	200	250	99.35	150.65	0.75	39.74
Field I	2	300	245	212.6	32.4	0.11	86.78	200	245	212.6	32.4	0.16	86.78
	3	300	241	199.8	41.2	0.14	82.9	200	241	199.8	41.2	0.21	82.9
Average					**107.87**	**0.36**	**56.56**				**74.75**	**0.37**	**69.81**
	1	400	175	132.3	42.7	0.11	75.6	300	175	132.3	42.7	0.14	75.6
Field II	2	400	169	125.61	43.39	0.11	74.33	300	169	125.61			74.33
											43.39	0.14	
	3	400	176	124	52	0.13	70.45	300	176	124	52	0.17	70.45
Average					**46.03**	**0.12**	**73.46**				**46.03**	**0.15**	**73.46**
	1	300	89	67	22	0.07	75.28	250	89	67	22	0.09	75.28
Field III	2	300	84	72	12	0.04	85.71	250	84	72	12	0.05	85.71
	3	300	83	70.69	12.31	0.04	85.17	250	83	70.69	12.31	0.05	85.17
Average					**15.44**	**0.05**	**82.05**				**15.44**	**0.06**	**82.05**

Table 7 Application efficency

		Shaldo							
	Field location in the scheme								
Location	U/S			M/S			D/S		
Stage	WAD (mm)	AMS (mm)	Ea%	WAD (mm)	AMS (mm)	Ea%	WAD (mm)	AMS (mm)	Ea%
Initial	68.89	19.2	36.75	63.2	20.4	32.4	59.95	19.75	39.3
Devel.	70.38	29.66	45.85	50.78	32.6	67.5	41.6	31.3	73.65
Mid	85.34	50.53	64.55	75.8	58.8	73.3	55.95	37.7	61.25
Average			**49.05**			**57.73**			**58.07**
		Temela							
Initial	75.82	17.51	31.11	58.83	18.03	30.71	43.18	17.08	34.43
Devel.	68.69	29.01	36.82	40.88	26.34	53.98	37.02	27.13	64.59
Mid	76.26	46.86	51.18	63.35	49.87	63.8	48.03	32.75	53.76
Average			**39.7**			**49.5**			**50.93**
	Yeguga								
Initial	68.94	18.11	28.72	52.3	17.39	28.25	51.77	16.02	33.82
Devel.	63.54	28.21	35.58	41.81	27.85	58.9	36.03	25.25	63.53
Mid	77.31	48.47	49.73	62.1	50.35	64.01	48.61	30.26	52.96
Average			**38.01**			**50.39**			**50.1**
	Degalu Bora								
Initial	73.31	19.2	36.75	63.2	20.4	32.4	59.95	19.75	39.3
Devel.	70.38	29.66	45.85	50.78	32.6	67.5	41.6	31.3	73.65
Mid	85.34	50.53	64.55	75.8	58.8	73.3	55.95	37.7	61.25
Average			**49.05**			**57.73**			**58.07**
	Beriti								
Initial	70.3	17.28	34.67	49.4	16.88	27.61	52.27	17.06	33.82
Devel.	65.26	26.78	43.61	39.4	26.84	57.67	36.3	27.11	63.53
Mid	79.98	45.78	61.92	58.39	48.17	62.77	48.86	32.75	52.96
Average			**46.73**			**49.35**			**50.1**
	Gusha Ejersa								
Initial	66.72	14.27	27.14	51.31	17.87	32.36	49.61	15.19	37.07
Devel.	67.11	25.04	44.63	47.55	28.79	55.66	39.05	30.76	70.06
Mid	62.73	47.66	52.86	57.11	42.88	60.38	41.76	33.71	58.75
Average			**41.54**			**49.47**			**55.29**
	Yeguga								
Initial	72.27	15.72	27.69	46.08	16.8	24.18	53.6	14.88	31.71
Devel.	63.46	23.72	34.89	40.61	25.98	65.94	39.14	23.41	59.12
Mid	64.88	47.49	48.37	71.49	49.63	65.58	41.04	27.98	48.91
Average			**36.98**			**51.9**			**46.58**

Table 8 Storage efficency

Temela									
Field location in the scheme									
Stage	**U/S**			**M/S**			**D/S**		
	SMD (mm)	AMS (mm)	Es %	SMD (mm)	AMS (mm)	Es%	SMD (mm)	AMS (mm)	Es %
Initial	15.36	16.51	67.28	17.25	18.12	80.13	21.74	16.8	74.18
deve.pt	25.67	24.74	85.37	30.57	29.38	86.17	22.63	28.19	86.17
Middle	40.17	42.04	75.19	48.97	58.16	69.04	49.54	30.12	85.98
Average	**27.07**	**27.76**	**75.95**	**32.26**	**35.22**	**78.45**	**31.3**	**25.04**	**82.11**
Shaldo									
Initial	15.15	16.34	89.42	19.14	17.67	82.48	18.81	17.46	86.36
deve.pt	30.91	23.85	78.68	29.33	25.31	76.58	25.98	25.27	74.5
Middle	40.18	41.17	85.63	49.78	50.06	79.59	49.23	32.19	81.86
Average	**28.75**	**27.12**	**84.58**	**32.75**	**31.01**	**79.55**	**31.34**	**24.97**	**80.91**
Yeguga									
Initial	15.39	14.74	68.17	15.86	19.49	75.47	21	18.38	83.69
deve.pt	31.46	25.56	80.06	27.56	26.9	70.21	28.27	26.76	76.61
Middle	43.74	47.44	70.31	45.99	50.07	72.02	39.63	29.47	67.5
Average	**30.2**	**29.25**	**72.85**	**29.8**	**32.15**	**72.57**	**29.63**	**24.87**	**75.93**
Gusha Elasa									
Initial	16.68	18.85	74.05	18.81	18.71	79.97	20.2	16.77	72.99
deve.pt	29.95	28.08	80.16	27.14	28.33	79.07	25.34	26.07	73.79
Middle	48.32	49.05	78.21	50.07	51.88	77.34	42.64	31.79	72.97
Average	**31.65**	**31.99**	**77.47**	**32.01**	**32.97**	**78.79**	**29.39**	**24.88**	**73.25**
Beriti									
Initial	15.39	15.97	76.82	18.43	20.18	71.46	23.4	15.78	85
deve.pt	30.64	25.41	87.99	24.16	27.92	75.57	29.79	25.19	88.38
Middle	39.54	42.99	87.52	50.87	50.92	79.69	39.83	33.34	87.35
Average	**28.52**	**28.12**	**84.11**	**31.15**	**33.01**	**75.57**	**31.01**	**24.77**	**86.91**
Hobori									
Initial	15.39	17.14	87.73	19.14	20.19	73.37	20.29	16.77	72.51
deve.pt	30.64	29.38	81.21	30.85	26.61	84.96	27.58	27.36	77.21
Middle	39.54	48.17	70.79	51.68	51.18	76.34	43.14	32.12	74.31
Average	**28.52**	**31.56**	**79.91**	**33.89**	**32.66**	**78.22**	**30.34**	**25.42**	**74.68**
Arabi									
Initial	16.68	20.85	72.05	18.81	18.71	79.97	20.2	16.77	72.99
deve.pt	25.55	28.08	80.16	27.14	28.33	71.07	25.34	26.07	73.79
Middle	48.32	49.05	78.21	50.07	51.88	77.34	42.64	31.79	67.1
Average	**30.18**	**32.66**	**76.81**	**32.01**	**32.97**	**76.13**	**29.39**	**24.88**	**71.29**

Table 9 Soil moisture content before and two days after irrigation

	Temela					
	Field location in the scheme					
Stage	SM (vol%)	**U/S**		**M/S**		**D/S**	
		0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	θBI	34.7	26.73	26.88	36.46	33.2	37.49
	θAI	42.31	39.39	41.5	35.49	43.76	39.84
Development	θBI	32.52	31.3	27.29	40.47	27.02	31.71
	θAI	33.73	36.68	45.23	46.44	33.68	32.67
Mid-season	θBI	28.52	31.6	35.41	26.79	31.62	34.46
	θAI	33.86	30.76	37.34	40.96	44.7	35.76
	Yeguga						
Initial	θBI	34.52	28.88	34.36	35.82	36.61	31.33
	θAI	32.71	39.43	36.85	34.57	34.13	36.79
Development	θBI	26.57	35.16	28.88	32.46	30.06	32.04
	θAI	37.34	31.02	43.04	34.87	44.28	38.15
Mid-season	θBI	36.03	33.84	37.39	31.87	34.02	35.13
	θAI	43.66	40.65	44.99	37.55	36.03	34.92
	Gusha Ejersa						
Initial	θBI	32.35	31.72	27.99	31.97	35.15	33.07
	θAI	39.9	39.1	35.42	38.16	39.79	38.91
Development	θBI	31.9	36.79	28.22	35.29	32.03	35.06
	θAI	40.45	38.81	35.54	38.31	40.11	39.44
Mid-season	θBI	34.61	32.8	31.58	30.84	31.3	34.71
	θAI	41.4	40.28	35.18	38.11	38.41	37.78
	Arabi						
Initial	θBI	32.79	32.8	27.19	31.34	35.5	33.18
	θAI	40.45	40.43	34.41	37.4	40.17	39.03
Development	θBI	32.33	38.03	27.4	34.59	32.34	35.17
	θAI	41	40.11	34.51	37.54	40.5	39.57
Mid-season	θBI	35.07	33.89	30.66	30.21	31.6	34.83
	θAI	41.96	41.6	34.14	37.34	38.78	37.9
	Shaldo						
Initial	θBI	27.52	34.2	35.3	38.25	41.45	37.99
	θAI	44.5	41.8	45	45.89	46.8	44.66
Development	θBI	35.45	39	36.1	42.65	37.58	40.21
	θAI	44.8	40.8	45.8	46.53	46.95	45.2
Mid-season	θBI	38.2	34.2	41	37.64	36.55	39.75
	θAI	45.55	41.65	46	46.76	44.75	43.22

	Beriti						
Initial	θBI	34.42	32.23	32.56	29.58	38.76	33.89
	θAI	40.82	33.55	34.02	43.54	33.65	35.22
Development	θBI	26.69	35.07	35.65	42.57	26.96	29.06
	θAI	33.44	37.7	39.56	33.12	40.62	39.19
Mid-season	θBI	28.4	25.25	33.29	32.97	36.51	32.89
	θAI	38.46	40.54	43.08	41.3	36.9	40.57
	Hobori						
Initial	θBI	29.07	27.53	28.52	30.59	36.89	31.28
	θAI	35.28	34.94	38.17	39.94	40.18	36.59
Development	θBI	27.91	32.43	30.69	37.16	32.36	32.77
	θAI	35.01	33.76	39.03	40.57	40.55	36.65
Mid-season	θBI	29.64	28.16	35.03	32.84	31.66	32.07
	θAI	35.09	34.12	39.39	40.84	38.88	34.69

Table 10 Distribution uniformity (%)

Temela						
Field location in the scheme						
Stage	U/S		M/S		D/S	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	91.2	87.4	85.9	87.5	86.8	85.7
development	88.1	91.11	89.3	88.4	88.9	89.1
Mid-season	90.2	86.7	89.8	82.4	90.5	86.6
Average	**89.12**		**87.22**		**87.93**	
		Beriti				
Initial	82.05	71.18	82.12	79.15	85.22	88
development	74.93	88.93	85.66	83.25	82.2	80.86
Mid-season	87.27	80.93	79.75	69.21	71.83	64.68
Average	**80.88**		**79.86**		**78.8**	
		Shaldo				
Initial	80.29	74.34	83.84	83.93	81.74	79.24
development	71.36	88.15	83.35	78.51	74.67	70.71
Mid-season	69.76	68.58	76.67	66.24	73.14	67.23

Average	**75.42**		**78.76**		**74.46**	
Initial	78.15	77.99	77.43	79.49	78.96	78.39
development	81.3	78.74	76.92	70.05	72.11	68.74
Mid-season	85.16	74.56	76.88	69.6	78	72.8
Average	**79.32**		**75.06**		**74.83**	
		Yeguga				
Initial	70.54	69.14	73.34	70.34	70.15	66.53
development	87.87	79.49	71.21	68.16	68.64	67.26
Mid-season	77.29	77.36	80.94	74.85	82.32	79.22
Average	**76.95**		**73.14**		**72.35**	
		Guhsa Elasa				
Initial	78.81	75.28	68.07	70.98	74.76	66.05
development	75.76	78	75.43	76.19	74.74	75.3
Mid-season	77.19	73.78	66.61	64.41	65.36	59.54
Average	**76.47**		**70.28**		**69.29**	
		Degalu bora				
Initial	77.87	70.26	69.42	67.93	66.71	64.68
development	70.25	70.25	68.94	66.73	66.65	66.08
Mid-season	81.3	78.76	81.69	75.38	83.01	79.71
Average	**74.78**		**71.68**		**71.14**	
		Hobori				
Initial	88.06	74.79	73.1	64.9	67.85	61.89
development	77.56	77.5	87.16	84.8	83.72	82.39
Mid-season	73.07	83.89	83.82	73.18	76.01	68.73
Average	**79.14**		**77.83**		**73.43**	

Table 11 Christiansen uniformity coefficient %

	Temela					
Stage	U/S		M/S		D/S	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	92.37	89.37	85.51	87.42	89.76	88.15
Development	86.84	91.11	89.3	88.4	86.95	89.09
Mid-season	89.06	88.78	87.27	88.82	90.53	90.8
Average	**89.59**		**87.79**		**89.21**	
		Gusha Elasa				
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	81.32	76.02	83.46	83.86	84.53	81.51
Development	70.34	88.15	83.35	78.51	73.03	70.71
Mid-season	68.88	70.23	74.51	71.4	73.16	70.49
Average	**75.82**		**79.18**		**75.57**	
		Hobori				
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	89.19	76.48	72.77	64.85	70.17	63.66
Development	76.45	77.5	87.16	84.8	81.88	82.38
Mid-season	72.14	85.9	81.46	78.88	76.04	72.06
Average	**79.61**		**78.32**		**74.37**	
		Yeguga				
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	89.37	83.42	75.94	73.43	71.24	65.84
Development	68.69	77.79	71.79	71.44	67.5	68.47
Mid-season	77.71	70.79	67.29	68.57	68.33	68.08
Average	**77.96**		**71.41**		**68.24**	
		Beriti				
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	71.15	80.4	69.64	83.57	81.19	86.54
Development	76.45	77.5	87.16	84.8	81.88	82.38
Mid-season	72.14	85.9	81.46	78.88	76.04	72.06
Average	**77.26**		**80.92**		**80.02**	
		Arabi				
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
Initial	78.5669	89.37	85.51	87.42	89.76	88.15
Development	86.84	91.11	89.3	88.4	86.95	89.09
Mid-season	89.06	88.78	87.27	88.82	90.53	90.8
Average	**87.29**		**87.79**		**89.21**	
		Degali bora				
Initial	79.05	76.05	63.43	68.34	64.83	60.61
Development	73.86	88.93	85.66	83.25	80.4	80.85
Mid-season	86.17	82.87	77.51	74.6	71.85	67.82
Average	**81.15**		**75.46**		**71.06**	

Table 12 Irrigation water anaiysis

Field location	Area (ha)	VWA(m^3/ season)	VWA (m^3/ ha/season)	Water Cost (Birr/10^3m^3)	TWC Birr/plot/season)	TWC (Birr/ ha/season)
U/S	0.0456	362	7,938.60	6	2.17	47.63
M/S	0.0368	375	10,190.22	6	2.25	61.14
D/S	0.0485	370	7,628.87	6	2.22	45.77
U/S	0.0456	293.24	6,430.62	6	1.76	38.58
M/S	0.0368	290.04	7,881.59	6	1.74	47.29
D/S	0.0485	369.02	7,608.73	6	2.21	45.65
U/S	0.0456	279.48	6,128.99	6	1.68	36.77
M/S	0.0355	341.12	9,608.96	6	2.05	57.65
D/S	0.04	300.12	7,503.09	6	1.8	45.02
U/S	0.0456	337.9	7,410.01	6	2.03	44.46
M/S	0.036	320.18	8,894.00	6	1.92	53.36
D/S	0.048	295.03	6,146.54	6	1.77	36.88
U/S	0.0456	305.92	6,708.82	6	1.84	40.25
M/S	0.046	257.84	5,605.25	6	1.55	33.63
D/S	0.0385	335.77	8,721.30	6	2.01	52.33
U/S	0.046	271.41	5,900.15	6	1.63	35.4
M/S	0.0385	343.98	8,934.55	6	2.06	53.61
D/S	0.0485	285.16	5,879.61	6	1.71	35.28
U/S	0.0456	328.84	7,211.47	6	1.97	43.27
M/S	0.046	297.17	6,460.14	6	1.78	38.76
D/S	0.0385	312.54	8,117.95	6	1.88	48.71

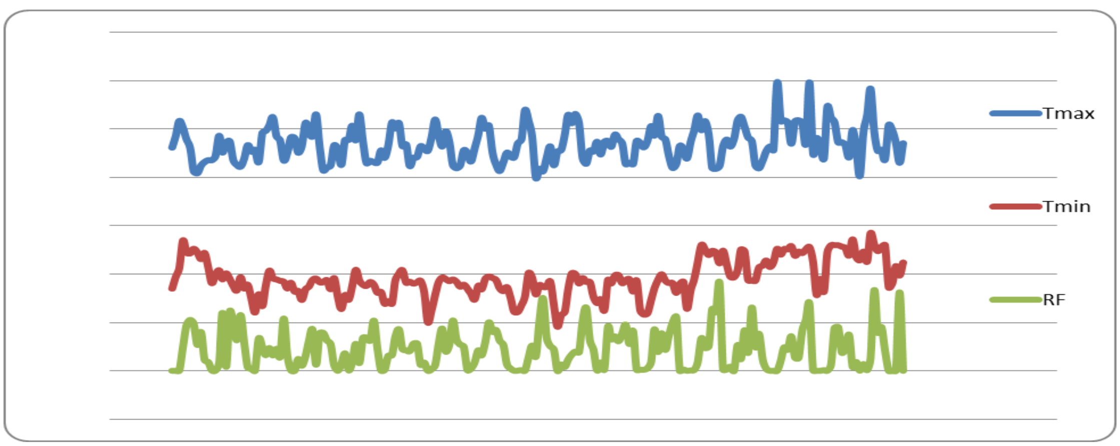

Figure 1 Annual climate of Kulumsa Meteorological station from 2000 to 2016

Table 13 Production per unit water applied

Field location	Area (ha)	WA(mm)	WA (m^3/ha)	Potato wt (Kg)	Potato wt (Kg/ha)	WPA Kg/m^3)	WPE (Birr/m^3)
U/S	0.0456	612.1	6,121.02	328.72	7,208.70	1.18	25.83
M/S	0.0368	593.73	5,937.26	280.86	7,632.07	1.29	34.93
D/S	0.0485	503.7	5,037.01	294.8	6,078.33	1.21	24.88
U/S	0.0456	623.57	6,235.67	334.66	7,338.96	1.18	25.81
M/S	0.0355	559.25	5,592.55	257.54	7,254.77	1.3	36.54
D/S	0.04	455.25	4,552.51	289.57	7,239.13	1.59	39.75
U/S	0.0456	564.79	5,647.91	321.43	7,048.96	1.25	27.37
M/S	0.036	622.31	6,223.08	289.99	8,055.33	1.29	35.96
D/S	0.048	506.97	5,069.70	296.24	6,171.72	1.22	25.36
U/S	0.0456	609.12	6,091.19	327.18	7,175.02	1.18	25.83
M/S	0.046	590.82	5,908.18	261.26	5,679.60	0.96	20.9
D/S	0.0385	500.64	5,006.44	264.32	6,865.56	1.37	35.62
U/S	0.046	649.71	6,497.10	291.41	6,335.06	0.98	21.2
M/S	0.0385	532.1	5,320.95	283.57	7,365.34	1.38	35.95
D/S	0.0485	497.42	4,974.20	305.87	6,306.69	1.27	26.14
U/S	0.0456	661.14	6,611.38	298.83	6,553.20	0.99	21.74
M/S	0.046	589.48	5,894.80	280.11	6,089.45	1.03	22.46
D/S	0.0385	469.34	4,693.43	267.97	6,960.17	1.48	38.52
U/S	0.046	667.02	6,670.20	368.4	8,008.70	1.2	26.1
M/S	0.039	557.95	5,579.51	325	8,333.33	1.49	38.3
D/S	0.048	460.11	4,601.09	342.8	7,141.67	1.55	32.34

Table 13 Mean monthly ETo (mm/month) and effective rainfall (mm/month) at Assela

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day	Rain mm	Eff rain Mm
January	10.30	22.40	39.00	61.00	8.80	20.70	3.59	0	0
February	10.30	26.20	36.00	39.00	9.70	23.30	3.96	0	0
March	12.10	27.30	30.00	10.00	8.40	22.30	3.72	30.8	29.3
April	13.40	27.20	29.00	10.00	8.50	22.60	3.86	0	0
May	13.00	25.70	57.00	12.00	6.30	18.70	3.51	148.5	113.2
June	13.40	24.20	62.00	13.00	6.40	18.40	3.42	145.2	111.5
July	12.80	23.40	67.00	13.00	7.50	20.20	3.64	62	55.8
August	12.90	23.40	67.00	13.00	6.50	19.20	3.52	76.8	67.4
September	12.30	22.80	67.00	13.00	5.90	18.40	3.33	112.9	92.5
October	13.60	24.90	42.00	13.00	7.20	19.70	3.41	12.7	12.4
November	12.50	24.50	46.00	12.00	8.30	20.20	3.37	30.2	28.7
December	11.40	23.10	50.00	14.00	7.80	18.80	3.10	0.3	0.3
Average	12.30	24.60	49.00	19.00	7.60	20.20	3.54	619.4	511.2

Table 14 Mean monthly weather data at kulumsa meteorological station from 2000 to 2016

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Aver.	Annual
2000	0.0	0.0	0.0	5.9	4.1	4.6	4.9	5.0	5.8	3.3	1.2	0.0	2.9	34.82
2001	0.0	2.9	8.6	1.7	8.4	5.8	4.5	8.8	4.1	1.3	0.3	0.0	3.87	46.41
2002	0.2	1.7	2.7	2.0	1.2	3.9	2.2	6.6	2.5	0.3	0.0	1.8	2.1	25.15
2003	0.3	0.5	5.6	6.0	1.2	3.3	4.8	5.0	3.6	0.2	0.1	1.1	2.63	31.57
2004	2.0	0.0	1.2	3.8	1.5	3.3	4.8	5.5	5.2	5.1	0.7	1.6	2.9	34.75
2005	2.9	0.7	3.8	4.2	5.9	2.5	4.3	4.9	4.0	0.5	1.3	0.0	2.91	34.93
2006	3.0	4.6	6.8	5.8	3.9	1.5	0.0	0.4	2.6	2.3	2.0	1.6	2.85	34.17
2007	0.8	2.5	0.8	4.0	5.7	4.2	7.4	6.6	4.5	1.6	0.4	0.0	3.21	38.52
2008	0.2	0.1	1.1	4.1	3.0	6.6	7.7	4.7	1.8	1.8	0.0	3.6	2.88	34.56
2009	1.6	0.5	2.5	2.4	2.4	3.7	3.8	4.2	4.7	5.1	5.6	6.0	3.53	42.36
2010	0.2	4.1	3.3	6.2	4.1	2.9	4.6	4.5	6.3	0.0	0.6	0.1	3.06	36.75
2011	0.3	0.8	3.3	2.3	4.8	2.6	5.8	6.0	6.4	0.0	1.1	0.0	2.78	33.31
2012	0.0	0.0	1.0	3.6	1.1	3.0	7.3	5.9	4.4	0.1	0.0	1.1	2.29	27.49
2013	0.4	0.0	5.2	1.7	5.2	1.7	9	3.1	4.1	3.2	0.9	0.0	2.88	34.57
2014	0.1	1.1	5.0	2.5	4.3	1.6	5.8	5.6	6.0	6.3	0.4	0.0	3.22	38.6
2015	0.0	0.0	0.6	0.9	3.5	6.3	3.9	5.4	5.7	0.3	5.3	5.7	3.12	37.49
2016	0.5	0.9	3.1	10.26	4.9	4.7	4.9	0.5	0.0	2.8	2.8	2.7	3.15	37.84

Table 15 Mean monthly ETo (mm/month) and effective rainfall (mm/month) of Kulumsa

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ETc mm/day	3.59	3.96	3.72	3.86	3.51	3.42	3.64	3.52	3.33	3.41	3.37	3.1
Rain (mm)	0	0	30.8	0	148.5	145.2	62	76.8	112.9	12.7	30.2	0.3
P (mm)	0.06	0.04	30.85	0.05	148.56	145.26	62.05	76.86	112.97	12.76	30.27	0.38

N.B. Effective rainfall calculated using the USSCS formulas:

Effective R. = (125 - 0.2 * Total R.)* Total R. / 125...... (Total R. < 250 mm/month),

Effective R. = 0.1 * Total R. - 125 ... (Total R. > 250 mm/month).

Table 16 Average infiltration rate of test plots Elapsed time Cumulative time

(min)	(min)	(mm)	(mm)	(mm/hr)
0	0	0		
2	2	3.0	3.00	90.00
2	4	1.9	4.20	65.20
2	6	2.0	5.00	54.00
2	8	1.3	6.30	40.00
5	13	2.7	9.00	32.40
5	18	2.7	11.70	32.40
5	23	2.3	14.00	27.40
5	28	2.0	16.00	24.40
5	33	1.9	17.90	22.80
10	43	3.4	21.30	20.40
10	53	3.2	24.50	19.00
10	63	2.7	27.20	16.20
20	83	4.8	32.00	14.50
20	103	4.1	36.10	12.20
20	123	3.6	39.70	9.90
30	153	4.9	44.60	7.70
30	183	4.7	49.30	7.50
30	213	4.7	54.10	7.50

Figure 2 some part of cultivable crops

Figure 3 some of distorted canals alignment

Figure 4 Canal water losses or logging

Hawassa University

Institute of Technology

School of Civil Engineering

School of Graduate Studies

A questioner designed for sample farmers

Dear respondents,

The principal objectives of this questionnaire is to understand critical evaluation of the performance of traditional irrigation system in Degaluna Tijo Wareda of Irrigation Project, such studies on the first community based traditional irrigation are useful to the planers and decision makers to draw the most appropriate irrigation development plans, which are based on food security, farmers need and priorities. You are kindly requested to give an answer freely and openly. Any information you give is to be kept confidential. Thus, your cooperation is very necessary to achieve the desired goal of the study. Make your answer in box sign $\boxed{X}$. Thank you for your cooperation in advance

SECTION I

Questioner for group/Individual Beneficiary

1.1. General

1.1. Research Site: Region………………. Zone ………….

Districts/Woreda………………………………….

Peasant Association...... …………………………Village……….............…………

Irrigation Block…………………

Interviewer full name: ……………………………. date of interview……/……/2008EC.

Time of Interview…………………………………………

1.2. Respondent identification number …………………………

3. Household Head: a) Full name ………………………………

b) Sex: 1. male ☐ 2. female ☐ 3. Age……… (Years)

d) Marital Status: 1. married ☐ 2. single ☐ 3. divorced ☐ 4.Widowed ☐

1.4. Educational status

1. Elder school ☐ 2. Reading and writing ☐ 3. First cycle ☐

3. Second cycle ☐ 5. High school ☐ 6. Other, specify ……………

1.5. Family Characteristics: How many family members do you have... …...............

1.6. Structure of the family:

Age category	Sex			Level of education see above
	Male	Female	Total	
≤ 14				
From 15 to 32				
From 33 to 65				
> 65				

1.7. What is the type of house you own and live in?

1) Traditional house ☐ 2) Corrugated iron roofed ☐ 3) Both ☐

2) Land resources and utilization

2.1. Do you have land for production and other activities? 1) Yes ☐ 2) No ☐

2.2. For what purpose have you used your irrigation land?

1. Seasonal crop ☐ 2. Food crops 3. Grazing land ☐ 4. Cash crop ☐

5. Any other specify...

1. Seasonal crop ☐ 2. Food crops 3. Grazing land ☐ 4. Cash crop ☐

5. Any other specify...

2.3. How do you get the irrigation land? 1. Succession ☐ 2. Land distribution ☐

3. If any system, specify it...

2.4. If yes, provide the following information about your all land holdings for 2003 E.C year

No	Type of Land use	Land class		Area amount Ha	
		Owned	Non-owned	Local(tined)	Ha
1	Irrigation land				
2	Rain fed				
3	Common grazing				
4	Other/specify				

2.5. What is the fertility of land on which you are irrigating?

1. Very good ☐ 2. Good ☐ 3. Bad ☐ 4. Very bad ☐

2.6. What kind of labor you do you use for irrigation activities?

1. Only manpower ☐ 2. Oxen ☐ 3. Tractor ☐

4. other, specify...

3.0. Relevance of the project

3.1. Is this irrigation project important to you?

1. Very much ☐ 2. Normal ☐ 3. Not that much ☐ 4. Completely not ☐

3.2. Is this irrigation project benefiting your livestock (Cattle, sheep's, goats, etc)?

1. Very much ☐ 2. Much ☐ 3. Note that much ☐ 4. Completely not ☐

3.3. Is your life changed after you start to use irrigation? 1. Yes ☐ 2. No ☐

3.4. If yes, what is/ are the indicators?

1. Construction of new house ☐ 2. Sending children to school ☐ 3.Food variety ☐

4. Income increase ☐ 5. Other please specify..

3.5. Are you willing to pay for the following?

1. Operation & maintenances fee 1. Yes ☐ 2. No ☐

3.6 water service fee 1. Yes ☐ 2. No ☐

4.0. Effectiveness of the project

4.1. Is your overall annual crop production increased? 1. Yes ☐ 2. No ☐

4.2. Do you follow the proposed crops from the project?

1. Yes ☐ 2. No ☐ 3. Sometimes ☐

4.3. If you answer for question 4.2 is no, why?

1. I don't know the proposed crop ☐ 2. I don't have the experience ☐

3. I don't have the capacity ☐ 4. I do have my own choice ☐

5. Other, specify..

4.4. If Yes for Question 2.1 which crops production are increased? (Only main crops)

No	Types crop	Agricultural land	Pre Production/ ha	Post Production/ ha
1				
2				
3				

5. Efficiency of the project

5.1. Is there water shortage for your plot? 1. Yes ☐ 2. No ☐

5.2. If your answer for the above question is yes why you do think is the reason?

1. There is shortage of water in the river 2. There is shortage of water in the pond

3. Water capacity is less as seepage 4. Water distribution management is poor

5.3 What is the mode of water distribution?

1. Crop type 2. Land size 3. Other, specify...

5.4. Do you feel you share equal water with every user in the scheme?

1 .Yes 2. No

5.5. If no, what do you think is the reason for the inequality?

1. Ethnicity 2.Political Power 3. Shortage of water 4 .Crop Type
5.Gender 6 .Others/Specify..

5.6. Are you able to get the amount of product you planned to get? 1. Yes 2. No

5.7. If Yes for the above question do you think it is related with water? 1. Yes 2. No

5.8. How? (For the above question)

1. There was excess water 2. There was enough water
3.Other specify...

5.9. The embankment earthen materials how to maintain?

1. Seasonal 2. Yearly 3. If any specify...

5.10. Which resource you think is short in your area?

1. Water 2. Agriculture land 3. Forest 4. Other specify......................

5.11. Why you think it is scarce/short of water

1. Population increase 2. Irrigation expansion 3. Infrastructure expansion

4. Other specify..

5.12. From where are you getting water for your consumption? (Multiple answers are possible)

1. Rain fall 2. From your nearest River 3.Ffrom your locality sparing

4. The project ☐ 5. Any another, specify...

5.13. If you give multiple answers for Q. 5.14 prioritize them

....

5.14. What are the primary uses of water?

1. Agriculture, ☐ 2. Domestic, ☐ 3. Industrial, ☐ 4. Other, specify.............

5.15. Is there water shortage for livestock? 1. Yes ☐ 2. No ☐

5.16. If yes what do you think the cause for shortage of water?

1. Scarcity ☐ 2. Management ☐ 3. Accessibility ☐ 4. Other, specify....................

5.17. Is the shortage seasonal or all the time 1. Seasonal ☐ 2.Always ☐
3. I don't know ☐

5.18. Do you think the climate change has an effect on the water availability?

1. Yes ☐ 2. No ☐ 3. I don't know ☐

5.19. Do you think the irrigation water use can create conflict? 1. Yes ☐ 2.No ☐

5.20. If your answer for Q. 3.25 describe ____

6.0. Institutional

6.1. Is there any water association in your irrigation area? 1. Yes ☐ 2. No ☐

6.2. If yes, what it is? 1. WUA ☐ 2. WUC ☐ 3. WUG ☐

4. Other, specify..

6.3. Do your water association has by law 1. Yes ☐ 2. No ☐

6.4. Are you a member of water user association 1. Yes ☐ 2. No ☐

6.5. Have you paid membership payment for your water association?

1. Yes ☐ 2. No ☐

6.6. Have you started to pay project cost recovery? 1. Yes ☐ 2. No ☐

6.7. Do you pay operation and maintenance fee (such as for fuel etc.)?

1 .Yes ☐ 2. No ☐

6.8. If you pay water fee, how do you pay? Based on

1. The land size ☐ 2. Crop type ☐ 3. Water amount ☐ 4. Quota ☐

5. Other, specify...

6.9. How do you get irrigation water?

1. Gravity ☐ 2. From the first pump /Pond ☐ 3. From second pump /pond ☐

6.10. Is there water theft (using without turn)? 1 .Yes ☐ 2. No ☐

6.11. If your answer is yes for the above question? Is there punishment by the water association?

1. Scarcity ☐ 2, Management ☐ 3, other, specify ☐

6.12. Do you think the punishment is enough? 1. Yes ☐ 2. No ☐

6.13. How do you see your water association?

1. Very Strong ☐ 2. Strong ☐ 3. Medium ☐ 4. Very weak ☐ 5. Weak ☐

6.14. The water user organization can manage the project starting from

1. Headwork ☐ 2. Branch canal ☐ 3. Field canal ☐

6.15. Is your water user organization committees report to the members about their activities and plans?

1. Yes ☐ 2. No ☐