PERFORMANCE EVALUATION OF MEDIUM AND SMALL SCALE IRRIGATION SCHEMES IN TIYO AND ZIWAY-DUGDA DISTRICTS OF ARSI ZONE, OROMIA, ETHIOPIA

TAHIR EDAO GENAMO

A THESIS SUBMITTED TO

THE DEPARTMENT OF WATER RESOURCE ENGINEERING SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Water Resources Engineering (Specialization in Irrigation Engineering)

OFFICE OF GRADUATE STUDIES

ADAMA SCIENCE AND TCHNOLOGY UNIVERSITY

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Advisor: Andinet Kebede (PhD)

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Approval sheet

We, the undersigned, members of the Board of Examiners of the final open defense by **Tahir Edao Ganamo** have read and evaluated his/her thesis entitled **'Performance Evaluation of Irrigation schemes in Tiyo and Ziway-Dugda Districts of Arsi Zone''** and examined the candidate.

This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master's in Water Resources Engineering (specialization in Irrigation Engineering)

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DECLARATION

I, Tahir Edao G**a**rnemo, declare that this is my own original work and that it has not been presented and will not be presented to any other university for similar or other degree award, and that all sources of materials used for the thesis have been duly acknowledged.

Tahir Edao Ganamo	________________
Student Name	Signature

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ACRONYMS AND ABBREVIATIONS

BD	Bulk Density
DPF	Deep Percolation Fraction
Ea	Application Efficiency
Ec	Conveyance Efficiency
Es	Storage Efficiency
ES	Scheme irrigation efficiency
ETc	Crop Evapotranspiration
ETo	Reference Evapotranspiration
FAO	Food and Agricultural Organization
FC	Field Capacity
GDP	Gross Domestic Product
GPS	Global Positioning System
H/H	House Hold
IR	Irrigation Ratio
IS	Irrigation Scheme
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
Kc	Crop Coefficient
LSI	Large-Scale Irrigation
M ha	Million hectares
m.a.s.l	Mean Above Sea Level
MSI	Medium-scale irrigation
O & M	Operation and Maintenance
OPUCA	Output per Unit Command Area
OPUIA	Output per Unit Irrigated Area
OPUWC	Output per Unit Water Consumed
OUPIS	Output per Unit Irrigation Supply
P	Depletion fraction
Pe	Effective rainfall

PWP	Permanent Wilting Point
RH	Relative Humidity
RR	Runoff Ratio
SSI	Small-Scale Irrigation
SWC	Soil and Water Conservation
USDA	United State Development Agency
WUA	Water User Association
WUL	Water use leader

ABSTRACT

Irrigation development has been identified as an important tool to stimulate economic growth and rural development, and is considered as a cornerstone of food security and poverty reduction in Ethiopia. While a lot of effort is being exerted towards irrigation development, little attempt is being made toward the performance of already constructed schemes. This study is an attempt to assess the performance of purposively selected irrigation schemes in Tiyo and Ziway Dugda district of Arsi zone, Oromia National Region state. To evaluate the performance of the irrigation schemes and to suggest possible interventions of enhancing their capacity, internal and external indicators were applied. To realize these objectives, structured household survey, group discussions, field observations, field measurement and literature review were used in data collection. As internal indicators conveyance, application, water storage efficiency, and deep percolation ratio were used at the head, middle and tail reach of each scheme. Moreover, external indicators of agricultural output, water supply, water delivery capacity were used for evaluating the schemes. The results showed that the conveyance, application and storage efficiency of 50 %,, 73 %, and 87.84 %, respectively at Ketar, 71 %, 70 %, and 87.14 %, respectively at Arata Chufa. Output per unit irrigated area, per unit command area, per unit irrigation supply and per unit water consumption as agricultural output performance were 140,356 Birr/ha, 142,716 Birr/ha , 10.75 Birr /m^3 , 12 Birr/m^3 respectively at Ketar and 227,124 Birr/ha, 195,326 Birr/ha, 9.43 Birr/m^3 and 16 Birr/m^3 respectively at Arata Chufa. Physical indicators revealed the irrigation ratio of 1.01 at Ketar , 0.86 at Arata and 1.15 of sustainability of irrigated area were found 1.43 at Ketar and 1.33 at Arata. The water user association's organizational function and legal enforcement bylaws were weak at the two schemes. These also attributed to illegal water abstractions and unfair water distributions in the irrigation schemes. These result in poor irrigation water management which causes inadequate water for production. The efficiency evaluation showed that each irrigation scheme would need improvement measures to maximize the performance. In general, in irrigation management and practice, frequent performance evaluation should be conducted to identify the critical level of the schemes.

Keywords: *Irrigation, Irrigation scheme, internal indicators, external indicators, efficiency, physical indicators, WUA organization.*

1. INTRODUCTION

1.1. Background

The majority of population of Ethiopia is dependent on rain fed agricultural production for its livelihood. However, estimated crop production is not close to fulfill the food requirements of the country. One of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development (Robel, 2005). Irrigated agriculture produces about 40 % of all food and fiber on about 20 % of all cropped land (FAO, 2000). Irrigation is highly expected to play a major role in the realization of Ethiopian food security and poverty alleviation strategy. It enhances agricultural production and improves the food supply and income of rural population. It also supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops (Seleshi, 2010). As such, irrigated agriculture is a productive user of resources; both in terms of yield per cropped area and in yield per volume of water consumed, if properly managed. The non-consumed fraction of the water causes a variety of undesirable effects ranging from water-logging and salinity within the irrigated area to downstream water pollution (Bos *et al*., 1997).

The irrigated agriculture is the most inefficient and much water consuming sector, which contributes globally about 70% of water withdrawal from different sources like aquifers, streams, lakes and it is over 90% in most of the least developed countries particularly Ethiopia (FAO, 2011). Without improved efficiency measures, agricultural water consumption is expected to increase by about 20% globally by 2050 (WWAP, 2002 cited by Yusef, 2004).

From this important viewpoint irrigation projects are widely studied, planed, implemented and managed throughout the country. The development of new irrigated farms and rehabilitation of old irrigation schemes through investment of high capital resources are being pursued these days to meet the ever increasing human needs for food, fiber and energy. However, little or no attention is given to the monitoring and evaluation of the performance of already established irrigation schemes. Whether traditional or modern, public or community managed many of the existing irrigation systems are deteriorating in their physical structures, operation and management, which cause poor productivity and inefficiency of irrigation schemes.

Irrigation schemes face various problems related to operation and maintenance, water management and sustainability, these problems have greatly reduced their benefits and challenged their overall sustainability (Molden et al., 1998). Performance assessment is used to identify the present status of the scheme with respect to the selected indicators, which help to identify why the scheme is performing and means of improvement. Low level of performance can be identified at any level and stage of irrigation systems. At system level, the status of cropping intensity and yields from many irrigated areas are usually unsatisfactory. At the level of water distribution, there are innumerable references in the form of inequity of water distribution leading to major disparities between head and tail areas, deficit water supplies and loss of production in some location, or excess water delivery. Of course performance evaluation needs relevant and reliable data which are rarely available in Ethiopia (Yusuf, 2004).

Evaluation of performance of irrigation systems has been increasingly stressed in recent years by many researchers and managers of irrigation schemes. In the field of irrigation system management, performance evaluation of irrigation system is the key issue. From the studies made by many researchers earlier; it can be estimated further that the worldwide irrigation efficiency was less than 40 percent. This has resulted in some negative environmental impacts. Many schemes currently operate significantly under their design capacity. Recent estimates indicate that the total irrigated area in Ethiopia is 640,000 ha around 4 to 5 % of the existing cultivated area and 12% of its irrigation potential (Seleshi *et al*., 2010). Moreover, scheme performance is estimated to be an average of 36 percent below design, implying a further loss of about 230 thousand hectares of irrigated land; about 1.9 billion metric tons of topsoil are lost annually, which negatively affects water and land resources and agricultural productivity (Seleshi *et al.*, 2010).

For performance evaluation of irrigation schemes, different indicators are used by different researchers. The project performance indicators can be classified into the following five main groups (Mukherjee, 2004): technical indicators, agricultural indicators and institutional indicators. Technical performance is investigated by the technical indicators. Agricultural aspects are evaluated by the agricultural indicators, socio viability and sustainability of the physical environment for irrigation. Institutional indicators measure the institutional capacity i.e. social capacity of the people and organizations for managing and sustaining certain system. Most of these indicators are applicable to all types of irrigation schemes ranging from simple gravity to highly technical computer-controlled systems (Mukherjee, 2004). It should be mentioned here that there is no agreed universal set of indicators for performance evaluation of irrigation project. The availability of data and different physical, social and economic environment influence the selection of indicators (Alam, 2006).

In view of the above performance indicators, knowing the efficiencies and the effectiveness of water use at farm level and to alleviate the current challenges caused by inefficient operation of irrigation system and poor management of irrigation water at Ketar, Arata Chufa, Bosha-01 and Bosha-02 irrigation scheme is found to be important for possible recommendations of improvement of the scheme. Since its inception, on-farm irrigation system evaluation studies had never been conducted on the performance of this irrigation schemes. So, the performance evaluation of the scheme would help to improve the performance of the irrigation system in terms of water and land efficiencies to identify causes for poor irrigation management system.

The study site is located within Oromia region of Arsi Zone in two district, Tiyo and Ziway irrigation schemes. According to Agricultural and Natural resource Office annual report of two districts, Tiyo district has an irrigable land of 2,300 ha and from this 1670 ha was irrigated in the irrigation season. Ziway district also has an irrigable land of 7,215 ha and from this 6,670 ha was irrigated in the irrigation season, included house hold level hand dug well irrigation, but due to data collection and recording gaps the reliability of the figure exaggerated (Annual report of wereda ARNRO, 2019). Therefore, it is reasonable to evaluate the performance of Ketar medium-scale irrigation schemes found in Tiyo district and Arata Chufa small-scale irrigation schemes found in Ziway Dugda district having the following general and specific objectives

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1.2. Statements of the Problem

Most irrigation schemes are performing below capacity with an estimated average performance of about 36 percent below design capacity. This implies that about 230 thousand hectares of irrigated land is a loss, from this small scale scheme account for 90 percent of the gap (Seleshi et al, 2010).

In Tiyo and Ziway Dugda district, five modern irrigation schemes and 36 traditional irrigation systems are operating from River, hand dug and springs water sources. Totally, the irrigated land estimated at about 2300 ha in Tiyo and 7215 ha in Ziway Dugda district. From the total irrigated area 453 ha, 150 ha and 847 ha, 6510 ha of land irrigated by modern irrigation schemes and traditional river diversion in Tiyo and Ziway Dugda district respectively. However, there are conflicts among irrigation water users due to water shortage and poor water management. Ketar and Areta Chufa irrigation schemes have been giving service for 35 and 16 years respectively. However the schemes have not been fully functional as expected, their performances are poor and the structures are under failure (Source: Werada report, 2019).

More generally there are many factors accountable for the poor performance of irrigation schemes at the existing conditions. Inappropriate irrigation practices lead to inefficient water distribution, non-uniform crop growth and excessive leaching losses in some areas and insufficient irrigation in others part of the field. All of these decrease the yield per unit of irrigated area against per unit water applied. As a result, performance evaluation of irrigation schemes plays a fundamental role in improving the productivity of irrigation schemes by identifying where the critical problem occurred (Yusuf, 2004).

Poor performance of irrigation systems as a whole may occur due to poor irrigation water management, poor organizational performance and on-farm agriculture activities. Inefficient irrigation water delivery results in low agricultural production due to poor organizational intervention. So it is important to know the inter-relation between the three irrigation components such as; irrigation water efficiency, on-farm management and irrigation organization (Solomon, 2016).

Besides the poor performance of the irrigations as stated earlier, evaluation of irrigation systems using the comparative performance indicators is not common; this study attempts to introduce the concept of comparative performance indicators (with some process indicators) as a tool to evaluate the performance of irrigations system endeavors in the study area. Therefore, it is reasonable to evaluate the performance of irrigation schemes found in Tiyo and Ziway-Dugda district of Arsi zone.

1.3. Objectives

1.3.1. General Objective

The general objective of this study was to undertake performance evaluation of Ketar and Arata irrigation schemes of Tiyo and Ziway- Dugda district in Arsi zone, Ethiopia.

1.3.2. The specific objectives

- To evaluate the irrigation efficiency of ketar and Arata irrigation schemes.
- To evaluate the land and water productivity of ketar and Arata irrigation schemes
- To evaluate organizational management of ketar and Arata irrigation schemes.
- To evaluate physical performance of ketar and Arata irrigation schemes.

1.4. Research Questions

1. What factors cause to lower the efficiency of irrigation area?
2. What are the main constraints that affect agricultural performance of irrigation schemes?
3. How is the irrigation scheme organization contributed for the management and sustainability of the schemes?
4. What are the main problems responsible for sustainability of each scheme?

1.5. Significance of the Study

This study will provide water management options, which can improve the irrigation system and sustainability in these schemes. The water management recommendation can be extended to other similar medium and small scale schemes in Ethiopia. And also information collected from the study help government policy makers, development agents, and NGOs to formulate appropriate policies, design effective evaluation and development programs. It provides information for research and academic institutes as well for stakeholders. It also used as a benchmark for development works and future studies.

1.6. Delimitation and Limitation

The study was conducted on two irrigation schemes in Arsi Zone, namely Ketar and Areta Chufa irrigation schemes, which are found in Tiyo and Ziway Dugda district. The study aimed to evaluate irrigation efficiency, agricultural indictors, physical indicators, organization indicators which causing poor performance of the schemes and suggest their mitigations. This is because of high potential which access and vicinity to Kulumsa Agricultural research institute to have some material and data used for study.

2. LITERATURE REVIEW

2.1. Irrigation Development in Ethiopia

2.1.1. Historical Irrigation Development in Ethiopia

Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops in Awash Valley. Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal irrigation schemes in the late 1950s in the upper and lower Awash Valley. In the 1960s, irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley (Selesh *et al*., 2010).

Modern small-scale irrigation (SSI) development and management started in the 1970s initiated by the Ministry of Agriculture (MoA) in response to major droughts, which caused wide spread crop failures and food insecurity (Kassa, 2001).

From 1974 to 1991, no large scale private capital investment was committed as a result of the prohibition of private land ownership or rental of land on commercial scale by the land reform proclamation of 1975 as per the socialist policy adopted by the Government. During this period public capital expenditure were concentrated on the development of state farms and producer cooperatives which contributed for less than 10 percent of the total production during that period (Kenneth, 1988).

2.1.2. Current Status of Irrigation Schemes in Ethiopia

In Ethiopia, about 90% of the irrigation potential in terms of land and water resources has not been developed so far. However, there have been many ongoing medium and large-scale irrigation developments in recent years. While about 47% of the developed area is under large-scale public irrigation schemes, mainly industrial crops such as Cotton, Sugarcane and various fruits are grown. About 65% of the irrigated area is under small-scale irrigation schemes, either modern or traditional. Traditional irrigation schemes are those developed by farmers themselves and are without permanent water diversion, conveyance, control and distribution facilities. Modern schemes are those equipped with basic irrigation infrastructure such as water diversion and flow control structures and conveyance and distribution systems. Modern small-scale schemes account for about 18% of irrigated area to date. Small-scale schemes are operated and managed by the water users themselves with little involvement of government agencies in some case (Dejen, 2012).

Much of the world's land is not cultivated. Irrigated land covers 230 M ha of our world (FAO, 2000). Ethiopia comprise 112 million hectares (M ha) of land. Cultivable land area estimates vary between 30 to70 M ha. Currently, high estimates show that only 15 M ha of land is under cultivation. For the existing cultivated area, our estimate is that only about 4 to 5 percent is irrigated, with existing equipped irrigation schemes covering about 640,000 ha (Seleshi *et al.*, 2010).

However, the study estimates total irrigable land potential of 5.3 M ha assuming use of existing technologies, including 1.6 M ha through rainwater harvesting and groundwater. Significant irrigation potential from the twelve-river basin surface water is about 3.7 M ha and an additional 1.1 M ha from groundwater and 0.5 M ha rainwater harvesting. The existing irrigation practices also have several problems on water management and design of irrigation structures. Consequently, the yield and soil and water resource are negatively affected and irrigation efficiency lowered below the required performance. The challenges includes amongst others closing the gaps between planning and implementation of irrigation projects, improving the performance of existing irrigation schemes, removing constraints on the scale-up irrigation projects and ensuring the sustainability of water resource for irrigation. Non-functionality is estimated at 17-35%; low functionality is much larger (FAO, 2011).

2.2. Irrigation Scheme Categories in Ethiopia

Many irrigation schemes in Ethiopia classified in two ways (based on size and infrastructure). According to Seleshi *et al*. (2010) irrigation schemes in Ethiopia is classified based on the size of the command area in three categories as below.

1. **Small-scale irrigation** systems (<200 ha), which are often community-based and traditional methods. Traditional irrigation has a long history in Ethiopia. During Derg regime period, very little attention was paid to small scale and traditional irrigation schemes constructed and managed by peasant farmers. The traditional small scale irrigation uses simple water diversions. It has been practical for decades in the high land where small farms could divert river, spring water seasonally for a limited dry season.

2. **Medium-scale irrigation** systems (200-3,000 ha), which is community based or publicly sponsored (Seleshi *et al.*, 2010). It is the responsibility of Ministry of Water Resource (MoWR).

3. **Large-scale irrigation** systems (>3,000 ha).which is typically commercially or publicly sponsored (Seleshi *et al.*, 2010).

2.3. Components of Irrigation System

Like all systems, irrigation systems are made up of several components or parts that interacting another. Irrigation systems are equally complex with multiple Interacting parts. According to Solomon (2016) there are three main constituents of irrigation systems; irrigation scheme, on-farm management and organizations (figure 2.1). .

Irrigation scheme is the Characteristics of the irrigation infrastructures and equipment (intake, canals and drainage ditches, water partition structures, etc.) and the irrigated area. Farmers and their organizations have to take in to account the technical, organizational and financial constraints related to O&M of their irrigation scheme. The irrigation scheme has two main sub-constituents of land and water constituents.

On-farm management refers to the land holdings and the production process of individual farmers. It results from choices and decisions made by farmers. The heads of the farming household make decisions regarding the selection of crops, and the allocation of labor, inputs and capital with due considerations to the constraints they face and the opportunities they want to use. It includes the type of crops, agricultural technologies, allocation of labor inputs and capital (farming tools, oxen, etc.), in the production process.

Organizational performance is an important factor of sustainability and productivity of irrigation systems. Group based irrigation systems imply an organization in charge of operation and maintenance activities. Small scale irrigation schemes, including their main water supply infrastructures, might be managed entirely by a WUA. The objective is greater user commitment, which can lead to more efficient use of the resources by helping to overcome many of the problems that public irrigation systems face, such as inequitable water distribution, corruption, inefficiency, drainage and poor operation and maintenance.

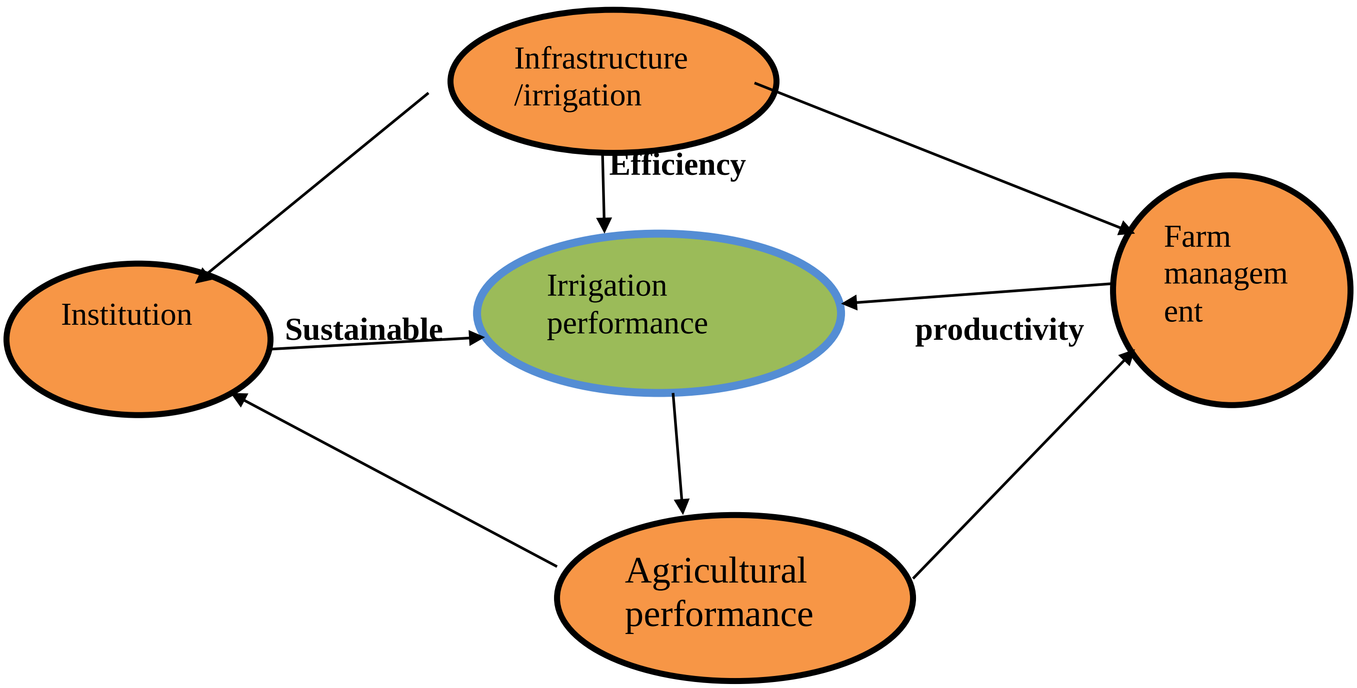

Figure 2.1: Modified the three main constituents of irrigation systems /Source: WUA guide line manual

2.3.1. Surface irrigation method practice

Surface irrigation is the application of water by gravity flow to the surface of the field. These systems are based on the principle of moving water over the surface of the land in order to wet it, either partially or completely. They can be subdivided into furrow, border strip and basin irrigation. (Zeleke, 2015).

According to FAO (1989), 95% of the irrigated area in the world is under surface irrigation. Some of the major advantages of surface irrigation systems over other systems are that they are easy to operate and maintain with skilled labor, they are best suited to soils with moderate to low infiltration capacities and land with relatively uniform terrain and slopes less than 2% (James, 1988). Surface irrigation systems do have also disadvantages. They are less efficient in water application than sprinkler or localized irrigation systems. The spatial and temporal variability of soil characteristics, such as infiltration rate and texture, make water management practices difficult to define and implement. It is also difficult to apply light, frequent irrigation required early and late in the cropping season. Another disadvantage can be the high labor demand, as compared to sprinkler and localized irrigation systems, in situations where labor is not abundant (Jadhav, 2014).

2.3.2. Basin irrigation

A basin is a horizontal area of land surrounded by earthen bunds and totally flooded during irrigation. Basin irrigation is the most common type of surface irrigation. It is particularly used in rice cultivation, where the fields are submerged, but it is equally suitable for other crops like cereals, fruit trees and pastures as long as water logging conditions do not last for too long. Ideally, the water logging should not last longer than 24-48 hours. It is also used for the leaching of salts by deep percolation in the reclamation (FAO, 2011).

2.3.3. Border strip irrigation

Border strips, border checks or strip checks are strips of land separated by small earth bunds that guide the water as it flows down the field. They can have rectangular or contoured shapes, depending on the field. The border strip slopes uniformly away from the direction from the source of the irrigation water. They should be leveled across, in order to allow for the even wetting of the whole area, covered by a border and allow free drainage at the end. Normally, water is let onto the field from the canals through siphons. The siphoned water spreads across the width of the border when there is no cross slopes, thereby facilitating uniform water application. Uneven border slopes and cross border slopes are some of the most common problems that result in low irrigation efficiencies (FAO, 2011).

2.3.4. Furrow irrigation

Furrow irrigation is accomplished by running water in small channels (furrows or corrugates) down the slope of a field. Water is conveyed to the field along the head of the field in open ditches. Various out let devices are used to divert water into each furrow. Outlets of equal size with uniform pressure head are desirable to deliver nearly equal flows to all furrows irrigated in one set. The type of conveyance system and outlet employed and degree of automation influence the capital cost of the system and the labor requirements process (Roger, 1997).

A furrow irrigation system consists of furrows and ridges, of which the shape, spacing and length depend mainly on the crops to be grown and the types of soils. Siphons are mostly used to take water from the field ditch to the furrows. According to Seleshi (2010), the width of the furrows varies from 250-400 mm, the depth from 150-300 mm and the spacing between the furrows from 0.75-1.0 m, depending on soil type, crops and stream size to be applied to the furrow. Coarse soils require closely-spaced furrows in order to achieve lateral water flow in the root zone. There is more lateral water flow in clay than in sand. Typical furrow lengths vary from about 60 m on coarse textured soils to 500 m on fine textured soils, depending on the land slope, stream size and irrigation depth. The minimum and maximum slopes for furrows should be 0.05% and 2% respectively in areas of low rainfall intensity. In areas where there is a risk of erosion due to intensive rainfall, the maximum slope should be limited to 0.3%.

2.4. Surface Irrigation Water Losses

All water taken from a source (river, well) does not reach the root zone of the plants. Part of the water is lost during transport through the canals and in the fields. The remaining part is stored in the root zone and eventually used by the plants. In other words, only part of the water is used efficiently, the rest of the water is lost for the crops on the fields that are to be irrigated. Irrigation water losses in canals are due to evaporation from the water surface, deep percolation to soil layers underneath the canals, seepage through the bunds of the canals, overtopping the bunds, bund breaks, runoff in the drain, and rat holes in the canal bunds (FAO, 1989).

Water management and determination of consumptive water use in irrigated agricultural settings depend on understanding factors such as surface-water diversions, groundwater withdrawals, evapotranspiration, tail-water runoff, and deep-percolation return flow of water beneath irrigated fields (Dinka, 2017). Water losses during surface (furrow) irrigation include runoff, evaporation from water in furrow channels, evaporation from the soil surface, and percolation below the root zone. Runoff losses can be significant if tail-water is not controlled and reused. In cases where runoff water is recovered and reused, the volume of irrigation water recovered and reused , the volume of irrigation water delivered to farm or field (Vf) should be adjusted to account for the net recovered tail water (Irmak, 2011).

Runoff is surface water that leaves the subject region in liquid form. Clearly, what constitutes runoff in a given region can be destined for infiltration and/or transpiration in a downstream region. Surface water captured and reapplied within the subject region is not classified as runoff from the subject area. It may be useful to note its temporary status, in connection with energy use for pumping or degradation in quality, but it does not enter into the water balance or considerations of efficiency if it is captured and reapplied within the boundaries (Burton *et al*., 1978).

Deep percolation is infiltrated water which moves below the root zone. For a crop with active roots throughout a root zone, almost all of the deep percolation will occur within a short time of the completion of irrigation. For water stored in a potential root zone (with no active roots), the concept of field capacity is more dynamic, and slow drainage (deep percolation) will occur for several months in a heavy, high clay content soil (Mamuye *et al.*, 2015, as sited by Dinka 2017).

High seepage in canals leads to an increase in the water table of the irrigated area resulting in yield reduction. Moreover, the loss of irrigation water through seepage in canals reduces the share of water availability for the newly irrigated area. Under such conditions, improving irrigation canals by lining minimize the water loss through seepage (Robel, 2005).

2.5. Irrigation Scheme Performance Assessment

2.5.1. Technical background on performance assessment

Performance is defined by different authors simply as knowing the extent to which an irrigation scheme achieved established objectives (FAO, 2000). According to Abernethy (1989) the performance of an irrigation scheme is represented by its measured levels of achievement in terms of one or several parameters which are chosen as indicators of the system's goals. Bos *et al*. (1997) commented, "performance assessment is despite its apparent simplicity a very complex task" and cited the definition of performance proposed by Murray-Rust and Snellen (1993) as the degree to which an organization's products and services respond to the needs of their customers or users, and the efficiency with which the organization uses the resources at its disposal or the extent to which the land and water resources in the irrigation schemes planned for allocation to different users and their spatial and temporal distribution in planning and operation stages follow the objectives of the irrigation scheme and **(**Mohtadullah,1993) the level of achievement of desired objectives.

An indicator is some number that describes the level of actual achievement in respect of one of the objective of irrigation system. Indicators are used to simplify the complex internal and external factors affecting the performance of irrigated agricultural system. Performance can be measured from process and output points of view. Process measures of performance relate to a system's internal operations and procedures whereas; output measures of performance examine the quality and quantity of the system's final output. The fact that an indicator service as a guideline for further decision making. It should be carefully chosen, measured and interpreted (Small and Svendsen, 1990).

Irrigation performance, whether bad or good, is the result of varieties of activities such as planning, design, construction, operation of facilities, maintenance and proper application of irrigation water and agronomic activities (Small and Svendsen, 1990). Facilitation and execution of these activities requires proper coordination of six functional processes of irrigation, i.e. personnel management and support, equipment management, financial management and accounting, and resources mobilization. Planning, design and construction of irrigation schemes are mainly dealing with creation of physical infrastructure to facilitate the capturing of water from its source and transportation up to the farm level. These physical facilities need to be properly operated to ensure the capturing, allocation and delivery of water at the right time and adequate quantity (Molden and Kloezen, 1998).

Gorantiwar *et al*. (2005) have summarized performance measures proposed by various researches into allocation type and scheduling types. Allocation types performance measures are those which need to be attained primarily during the allocation of the resources at the planning and operation stages. Productivity and equity are performance measures under allocation type category. Scheduling type performance measures consists of irrigation scheduling, i.e. temporal and spatial distribution of irrigation water to the users. This measures adequacy, reliability, flexibility, efficiency and sustainability.

Scheduling should be such that water deliveries need to be adequate both in planning and operation, reliable, flexible and sustainable. The same authors grouped these two categories of performance measures into: economic (productivity), social (equity), environmental (sustainability) and management (reliability, adequacy, efficiency and flexibility). Conveyance efficiency is used to compare the amount of water delivered at the turnouts of the main irrigation conveyance network to the total amount of water delivered into the irrigation scheme. Its measurement is important in that water allocation plans are developed using estimated efficiencies of water flow at various stages and time (Gorantiwar *et al.*, 2005).

2.5.2. Reason of doing performance assessment

The evaluation of surface irrigation at field level is an important aspect of both management and design of the system .Field measurements are necessary to identify management practices and system configurations that can be feasible and effectively implemented to improve the irrigation efficiency. The evaluation may also show opportunities for improving performance through changes in the field size and topography. Evaluations are useful in several analyses and operations, particularly those that are essential to improve management and control (FAO, 1989).

According to Molden *et al.* (1998) performance is assessed for a variety of reasons**:** to improve system operations, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to find out what is causing wrong thing, to assess impacts of interventions, to diagnose constraints, to better understand and determinants of performance, to understand the detailed workings of an irrigation scheme in order to draw generalized inferences, and to compare the performance of a system with others or with the same system over time.

2.5.3. Factors Affecting Performance Irrigation Schemes

According to Solomon (2016) the factors that account for under performance of irrigation schemes include, among others:

- Poor system management and service provision,
- Poor understanding of farmer priorities and inadequate markets for produce,
- Lack of clear and sustainable water rights accorded to users, at on individual or group
- Lack of clear and recognized responsibilities and authority vested in the managing organizations,
- Lack of transparent accountability; and supporting incentives for the managing entities.
- Different performance gaps occur with irrigation system.

There are four potential kinds of performance gaps that can occur with irrigation systems (Yusuf, 2004).

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

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

The **third** kind of performance gap is a difference between management targets and actual achievements. Examples of management targets are the size of area served by irrigation in a given season, cropping intensity, irrigation efficiency, water delivery schedules and water fee collection rates. This can be called a gap in achievement. Such problems are generally addressed either by changing the objectives (especially simplifying them) or increasing the capacity of management to achieve them such as through increasing the resources available or reforming organizations.

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

Furthermore, Yusuf (2004) has discussed on irrigation efficiencies and identified some of the causes of irrigation inefficiencies as performance gaps. There are two reasons for this inefficient use of water: Leakage from unlined canals or from breakages in the canal system; and Faulty use of irrigation water (over-watering or under irrigation).

2.5.4. Irrigation performance indicator

To evaluate the performance of irrigation systems a set of recognized and accepted parameters are required. According to FAO (1993) among the factors used to judge the performance of an irrigation system or its management, the most common are application efficiency and distribution uniformity. This parameter can be subdivided and defined in a multitude of ways, as well as named in different manners. There is not a single parameter, which is sufficient for defining irrigation performance (FAO, 1989).

Small and Svendsen (1990) considered part of an agricultural economic system. For each of the systems, process, output, and impact measures can be considered. Process measures refer to the processes internal to the system that lead to the ultimate output, whereas; output measures describe the quality and quantity of the outputs where they become available to the next higher system.

Oad and Sampath (1995) and Bos *et al*. (1997) summarize the performance indicators currently used in the research program on irrigation performance (RPIP). Within this program field data are measured and collected to quantify and test about 40 multi-disciplinary performance indicators. These indicators cover water delivery, water use efficiency, maintenance and sustainability of irrigation, environmental aspects, socio-economic and management. He also noted that it is not recommended to use all described indicators under all circumstances. The number of indicators you should use depends on the level of detail with which one needs to quantify (e.g., research, management, information to the public) performance. IWMI (2007) explain performance indicators of irrigation can be broadly categorized into internal and external indicators.

Performance indicators can be broadly categorized into internal and external indicators. However commonly efficiency terms used for on-farm irrigation system evaluation (internal process indicators) include conveyance efficiency, application efficiency, uniformity, storage efficiency, adequacy, and recently complementary terms such as runoff ratio, deep percolation ratio, are being applied (Jurries, 2011).

2.5.4.1. Internal performance indicators

Internal performance indicators describe the effectiveness of the physical system and operating decisions to deliver irrigation water from a water source to the crop. Internal indicators examine the mechanisms of water control and allocation at all levels of the project and the efficiency with which the water is conveyed through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field (Irmark *et al*., 2011)

Generally, internal indicators enable a comprehensive understanding of the processes that influence water delivery service and the overall performance of a system. Internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated and cropping patterns (IWMI, 2007).

A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of system management and performance measures tell how well the system is performing relative to these targets. When the performance is not adequate, either the process must be changed to reach the target, or the target itself must be changed. Generally, internal indicators aid for checking the accuracy of activities related to irrigation management (Murray-Rust and Snellen, 1993).

Kloezen and Garces-Restrepo (1998) reviewed different literatures and summarizes that process (internal) indicators help system managers to monitor the quality of daily and seasonal operational performance. However; numerous studies focus on number of process indicators. Common internal performance indicators defined in the literature include:

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

2.5.4.2. External (comparative) performance indicators

Molden *et al*. (1998) described this category of indicators as those that analyze the inputs into and outputs from irrigation projects such as land, labor, water, cost of scheme operation and maintenance as well as the value of production. Many indicators of external performance are computed by using secondary data rather than primary data. The indicators tell general concept about the relative health of the irrigation system, yet they are not too data-intensive to discourage widespread and regular application. This is important to identify whether the scheme is performing in economic manner related to the consumption of scarce water resource (Molden *et al*., 1998).

The IWMI (2007) proposed a minimum number of external (comparative) indicators of four, two, one and two for agricultural outputs, water supply, delivery capacity and financial respectively. They are important for comparison of performance between different schemes for study of the impacts of management interventions. However, Common comparative indicators defined in the literature include:-

- agricultural performance indicators: Such as output per unit cropped area, output per unit command, output per unit irrigation supply, output per unit water consumed
- water use indicators (Relative Water Supply and Relative Irrigation Supply
- economic and environmental indicators

2.5.5. Evaluating both internal and external performance indicators

An irrigation system, consisting of a water delivery and a water use sub-systems, can be conceptualized to have two sets of objectives. One set relates to the outputs from its irrigated area, and the second set relates to the performance characteristics of its water delivery system. The purpose of evaluating both the external and internal indicators of an irrigation scheme is to reflect all the organizational dimensions and identify system components that require maintenance or modernization. In the developing world, where economies are based on agriculture, it is necessary to carry out thorough irrigation performance assessments using both categories of indicators (Oad and Sampath, 1995)

Good performance is not only a matter of high output, but also one of efficient use of available resources (Rust and Snellen, 1993).There are many negative impacts caused by inefficient operation of irrigation systems. Improper irrigation practices lead to inefficient water distribution, non uniform crop growth, excess leaching in some areas and insufficient leaching in others, all of which decrease the yield per unit of land area against per unit of water applied (1999). Efficient farm irrigation practices achieved through improving the efficiencies lead to improvement in crop production and economic viability of irrigated farm

2.5.6. Selected performance indicators

2.5.6.1. Internal performance indicators

Water delivery indicators are evaluating whether the system delivers water at the required rate at the right place and time and to assess whether the water delivery service is healthy, Adequacy, Efficiency (E), Equity indicator (EI) are the main indicators of internal water delivery performance (Irmark *et al*., 2011).

A comprehensive methodology has been proposed by Bos *et al.* (1994) and Bos *et al*. (1997) for evaluating the efficiencies at different levels in the irrigation scheme. These include water conveyance efficiency, water application efficiency, soil water storage efficiency, overall irrigation efficiency, and effective irrigation efficiency. Michael (2008) also put as a remark that the primary performance indicators are: conveyance efficiency, storage efficiency, application efficiency and distribution uniformity.

I. Conveyance Efficiency (Ec)

Conveyance efficiency is an indicator which measures irrigation water is normally conveyed from a water source to the farm or field through natural drainage ways, constructed earthen or lined canals, or pipelines. Many conveyance systems have transmission losses, meaning that water delivered to the farm or field is usually less than the water diverted from the source. Water losses in the conveyance system include canal seepage, canal spills, evaporation losses from canals, and leaks in pipelines (Irmark *et al*., 2011).

Irmark *et al*. (2011) also defined conveyance efficiency as; Irrigation water is normally conveyed from a water source to the farm or field through natural drainage ways, constructed earthen or lined canals, or pipelines. Many conveyance systems have transmission losses, meaning that water delivered to the farm or field is usually less than the water diverted from the source. Water losses in the conveyance system include canal seepage, canal spills, evaporation losses from canals, and leaks in pipelines. The water conveyance efficiency is defined as the ratio between the irrigation water that reaches a farm or field to that diverted from the water source.

Awulachew and Ayana (2011) found a conveyance efficiency of 88.7% in Bilate irrigation scheme in Ethiopia. Bayan (2017) reported a similar finding that unlined conveyance efficiency of Mada Batu small-scale irrigation scheme canals ranged from 47.1 to 88.6%. Conveyance efficiency at main canal of Selgie irrigation scheme, which is ranges from 69 % to 81 % as reported by Menelik (2008). While In contrary, the conveyance efficiency in the main unlined canal of Midhegdu small-scale irrigation scheme was 88.8 % as reported by Worku (2013).

II. Application Efficiency (Ea)

Water application efficiency (Ea) provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. After the water reaches the field supply channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the application efficiency (Irmark *et al*., 2011). It is the most important in terms of design and management since it reflects the overall beneficial use of irrigation water (FAO, 1989).

Worku (2013) noted that the concept of water application efficiency can be applied to a farm, can vary from extremely low to values approaching 100%. The depth of water applied is a dominant factor influencing efficiency of application. Even if water spread uniformly over the land surface, excessive depths of application would result in low efficiencies. Many variable factors such as land uniformity, irrigation method, size of irrigation stream, length of run, soil texture, permeability, and time the irrigator keeps water running on his farm and hence the depth he applies can influence the application efficiency.

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) .

Gashaye *et al.* (2008) reported that the application efficiency was 57.4, 44.4 and 49.3 % at the head, middle and lower end of Geray irrigation scheme respectively. Similarly, Dessalew et al (2016) reported that application efficiency in Bedene Alemtena small-scale irrigation scheme ranges from 53.6 % at the head to 57.2 % tail of the scheme. FAO (1993) reported that the attainable application efficiency according to the US (SCS) ranges from 55%-70%.

III. Storage Efficiency (Es)

According to FAO (1989), the water requirement efficiency, is also commonly referred to as the storage efficiency (Es). It is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root zone. The value of Es is important when either the irrigations tend to leave major portions of the field under-irrigated or where under-irrigation is purposely practiced to use precipitation as it occurs and storage efficiency become important when water supplies are limited (FAO, 1989).

FAO (1992) specified as water stored in the root zone is not 100% effective. Evaporation losses may remain high due to the movement of soil water by capillary action towards the soil surface. Water lost from the root zone by deep percolation where groundwater is deep. Deep percolation can persist after attaining field capacity. Depending on the weather, type of soil and time span considered, effectiveness of stored soil water might be as high as 90% or as low as 40%.

IV. Adequacy of irrigation

Bos *et al.* (1994) defines Adequacy deals with water supply to the crop relative to its demand. The measure of adequacy, relative water supply (RWS) is the most comprehensive. When the supply matches demand exactly, adequacy is one, however when supply exceeds demand, adequacy will be more than one. Hence the water supplied or allocated in excess of demand (if any) should not be considered for estimating the adequacy. The adequacy may be reduced with deficit irrigation as less water may be delivered than the maximum crop water requirement or the interval between irrigation water deliveries may be prolonged. Adequacy shows the degree to which the total water deliveries are sufficient to satisfy the needs of the crops in the crop season.

Zeleke (2015) reported average spatial and temporal values of adequacy are 0.69, 0.71 and 0.52 in October, November and December, and 0.9, 0.59 and 0.5 at head; middle and tail reach of the system respectively. The overall adequacy value of the system is found to be 0.64. The spatial and temporal average adequacy of the scheme is poor except in the head reach of the distribution system. The temporal adequacy in the head reach falls in the good range. However, the overall average adequacy during the season for the entire command of the main canal is found to be poor.

V. Equitable irrigation water distribution

Gorantiwar *et al*. (2005) expresses, Equity is the degree of variability in the relative water delivery from point to point over the irrigated area and it is a measure of the spatial uniformity of the water deliveries and shows the fairness of water delivery across the delivery points

Now a day, equity is become a critical issue in case of distribution of irrigation water. Besides, in many parts of the world, tail end farmers are facing problems with inequity in case of irrigational water distribution.. However, maintaining equity in irrigation sector is not an easy task especially in a developing country. Thus the allocation of water to achieve the maximum productivity is not the only objective but to allocate those resources such as water and area equitably according to the prevailing equity objectives is necessary to ensure social justice (Kalu, 1995).

However we feel that when water is scarce and managed optimally, the productivity and equity become conflicting issues. In this case, in the process of achieving equity, water allocated to more productive areas (e.g. the head of the system with lower conveyance losses) gets diverted to less several researchers have defined equity from different perspectives (Kalu, 1995).

Zeleke (2015) reported that the average spatial and temporal values of equity are 0.23, 0.32 and 0.48 in October, November and December, and 0.05, 0.3 and 0.27 at head; middle and tail reach of the system respectively. Equity of water distribution in November and December is perceived above the standard of the faire rage; which is said to be poor. But, the distribution of water in October is fair.

2.5.6.2. External performance indicators

A number of indicators are developed regard to External performance indicators. Those indicators relate the output to unit land and water. In addition, agricultural output indicators provide the basis for comparison of irrigated agriculture performance where water is a constraining resource. Output per unit water may be more important, whereas if the land is a constraint relative to water, output per unit land may be more important. It includes four basic comparative indicators as Molden *et al*. (1998) described below:

I. Output per unit irrigated Cropped Area (OPUIA)

It is computed as the total value of production per harvested area in the irrigation seasons. The output per unit irrigated cropped area quantifies the total value of agricultural production per unit of area harvested during the period of analysis. The annual harvested area depends on the cropping intensity. The area is the sum of all the areas under crops during the year in this case. This indicator is not affected by the intensity of cropping (irrigation). However, it can also indirectly indicate the degree of irrigation water availability. In addition to water availability, soil type and fertility, land suitability, crop variety, and agricultural inputs do have a significant impact on output and hence on land productivity. It is given as the ratio of production at local or world price to irrigation cropped area (Molden *et al*., 1998).

For the outputs per unit cropped area of the value of crop production with project situation 5097.73 and 2292.3 birr per hectare for Bobe and Laku respectively concludes that, the income per cropped area at Bobe is better productive than Laku scheme, these is due to proper management for Bobe irrigation scheme. According to Solomon 2016, Output per unit irrigated area values of 2198$/ha and 1356$/ha were calculated at Jari and Aloma SSI schemes, respectively. The agricultural output performance such as OPUIA were 4213.97 US$/ha, at Wosha irrigation scheme

II. Output per Unit Command Area (OPUCA)

This indicator quantifies the value of production that obtained per unit command irrigable area. The computed value indicates the level of utilization or number of cropping frequency of the given command area in the production year and the productivity of the command area. Smaller values of this indicator can also imply, less intensive irrigation and vice versa. It is particularly important where land is a constraining resource for production, which is a ratio of total value of production at local, or world price. Furthermore this is more relevant for land is the major constraint factor for production. Command area is the nominal or design area to be irrigated (Molden *et al*., 1998).

According to Değirmenci (2017) output per area unit command of 14 irrigation scheme found in turkey was range from 2387 to 10129 US$/ha during the irrigation season between 2011 and 2014. The output per command area is 22203.8 birr/ha and 23680 birr/ha for Bobe and Laku respectively, for year 2007. Solomon (2016), output per unit command area of Jari (3464$/ha) was three fold higher than the value of Aloma (1061$/ha).

III. Output per Unit Irrigation Water Supply (OPUIS)

The output per unit irrigation water supply tells on how well the total annual diverted irrigation water from a source is productive. Irrigation water supply includes conveyance (seepage) losses in canals, and hence it is generally measured at the intake from the source or at diversion. In areas where water is scarce, water management aims to increase the output per drop of irrigation water that is a ratio of total value of production at local or world price to the volume of surface irrigation water diverted to the command area. It is an important parameter where water is a scarce resource. Diverted/supplied irrigation water is the volume of surface irrigation water diverted to the command area. (Zeleke, 2012; Molden *et al*., 1998).

The output per irrigation supply is 3.26 birr/m^3 and 1.45 birr/m^3 for Bobe and Laku in the year 2007 and 2008. Output per unit irrigation water supplied (OPUIS) values of 0.47$/$m^3$, 0.89$/m^3 Aloma and Jari schemes were calculated, respectively. The output per irrigation supply is 1.77$/$m^3$ at Wosha irrigation scheme.

IV. Output per Unit Water Consumed (OPUWC)

This indicator derived from the general water accounting frame work consumed water is the actual evapotranspiration or process consumption from only irrigated crops (ET). It excludes other losses and water depletion from the hydrological cycle. The computed value does not affected by water losses through the system but only affected by the climatic feature of the area. It used to observe water consumption of crops at scheme level through evapotranspiration relative to the diverted and delivered amount of irrigation water (Molden *et al*., 1998).

2.5.6.3. Physical performance indicators

Physical indicators are related to the changing or losing irrigated land in the command area for different reasons. Among these, water scarcity and input availability are the main reason why lands in command area are not fully under irrigation in a particular season. From physical performance irrigation ratio and sustainability of irrigated area are the two main indicators as illustrated by Mekonnen and Awulachew *(*2009).

I. Irrigation Ratio (IR)

Irrigation ratio is the ratio of currently irrigated area to irrigable command area. It tells the degree of utilization of the available command area for irrigated agriculture at a particular time. Shortage of irrigation water, lack of irrigation infrastructure, lack of interest on irrigation due to less return, reduced productivity due to problems such as salinization and water logging, etc., could result in underutilization of land. On the other hand; cropping intensity is a ratio of annual cropped area to nominal irrigated area is indicative of annual land utilization. According to Burton (2000), cropping intensities from 100 to 200% are considered good.

II. Sustainability of Irrigated Area (SIA)

Sustainability of irrigated area is the ratio of currently irrigated area to initially irrigated area It is a useful indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator would mean the abandonment of lands, which were initially irrigated and hence, indicate contraction of the irrigated area over time. On the other hand, the values higher than unity indicate expansion of irrigated area and this imply more sustainable irrigation (Bos, 1997).

2.5.6.4. Organizational indicators

Most irrigation schemes suffer by multi-faced problems including management and organizational problems, lack of access to credit and input and marketing facilities. The scheme technically the structures deteriorated before their service life and some of them are left unused. With this issue, Hennok (2018) argue that inefficient and under-utilization of available capacity of the schemes in Ethiopia arises from giving more emphasis to technical aspects and less emphasis to the managerial and institutional issues.

The managerial and institutional issues can be evaluated quantitatively and qualitatively (Solomon, 2016) in the form of:

- Organizational structure and functions of WUAs
- WUA’s by-laws and enforcement; conflict resolution mechanisms
- Fee collection (membership, water fee)
- Beneficiary participation in operation and maintenance
- Water allocation and distribution

2.6. Determination of Existing Condition

2.6.1. Determination of crop water and irrigation water requirement

Despite the fact that the physical determination of crop water requirements (CWR) irrigation schedules and depths, is complicated and time consuming. They remain vital to irrigation management and planning (Yusuf, 2004).

The introduction of computer models has made it easier and possible to schedule irrigation and supply the exact amounts of water required by crops at every physiological stage in their growth cycle. Examples of such models include CROPWAT-8.0 (Clarke D, 1998). CROPWAT 8.0 computer program was used to estimate the total water requirements of major grown crops in the irrigation schemes. Using CROPWAT-8.0 calculate the reference crop evaporation (ETo). To determine ETo values the model requires crop data climatic data; mean monthly minimum and maximum temperature (°C), relative humidity (%), wind speed (km/day) and sunshine hours (hr) from nearby metrological station and crop data and the value of Kc of each major crops were taken from FAO I & D 24 (1992) and 56 (1998) papers.

2.6.2. Flow rate measurement at field

In many irrigation and drainage systems measurement of flow rate is an essential component of the operation process. Flow rate measurements need to be made in rivers, canals, drains and pipelines and can be made in a variety of ways which included hydraulic structures, slope-hydraulic radius, water collection at the downstream end of the open channels and velocity-area method. The Velocity-area method is recommended for temporary flow measurements such as research studies and in the absence of hydraulic structures (Zeleke, 2015).

2.6.2.1. Velocity-area method

The Velocity–area discharge measurement involves the measurement of the channel cross-sectional area and the average velocity of flow. The cross-sectional area is measured using a tape and level staff, the average flow velocity is determined with a float method. The selection of the method is however dependent on several factors which include cost, geometry of the canal, water quality, required accuracy (Solomon, 2016).

The float method is a simple, yet relatively effective way to determine the discharge of a flow stream. It is not that accurate (possibly to within ±20−30%), but is a considerable improvement on a visual estimation of discharge. It is well suited to smaller channels, less so to larger channels where the variation in velocity across the channel will change significantly (Zeleke, 2015).

The flow cross-sectional area is determined at each cross-section to allow for computation of flow rates from the continuity Equation 2.6.1:

$Q = V * A$ -- (2.6.1)

where:

Q = discharge [m3.s^{-1}],

V = average velocity [m.s^{-1}], and

A = flow cross-sectional area m^2

The velocity-area method is complex compared to using hydraulic structures; but it has several advantages over other methods, such as:

- It can be used where there are no weirs or flumes constructed,
- The method can be used with a variety of channel shapes,
- The method is more accurate than hydraulic-radius method, and
- There is minimal flow obstruction when using this method
- Cross-sectional areas of the channels are calculated differently depending on the variations in geometry of the channels.

2.6.2.2. Weirs

The weirs should be used for measuring discharges with head less than 0.066 m and 0.3 m of the minimum length of the weir in open channels. The discharge values obtained by weir measurements vary from 95 – 105 % of the true discharges (Hennok, 2018).

2.6.2.3. Partial flume

Partial flume a type of constricted standing wave flume widely used for discharge measurement at farm level (Hennok, 2018). The total amount of water requirement estimated using the CROPWAT version_8 program was diverted to the furrow with calibrated partial flume having appropriate opening diameter of three inch (3") with a length of 2 m and its appropriate head ranges from 3-33cm. Water flow to each furrow was controlled by the difference in depth between the water level in the feeder canal and free water level at the outlet at the furrow head. It was calculated as suggested by Michael (2008):

$$Q= 0.1771h^{1.55} \text{--} (13)$$

Where:

Q = discharge from partial flume (l/s),

h = effective head of Parshall flume causing flow (cm),

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study has been conducted on two community managed irrigation schemes (Ketar and Arata Chufa medium and small irrigation scheme respectively) for detail investigations which are believed to have large contribution to income for community. The schemes are situated in Tiyo and Ziway Dugda werada of Arsi Zone in Southeast of Oromia Regional state of Ethiopia.

3.1.1. Tiyo District

Tiyo district is found in Arsi zone, South east of Oromia regional state. It is located 175 km far from Addis Ababa in the Southeast direction. The administrative center of the woreda and Zone is Asella; other towns in Tiyo include Gonde and Golja. A survey of the land in this woreda shows that 40% is arable or cultivable (32% was planted with cereals), 23.1% pasture, 8.7% forest, and the remaining 28.2% is considered swampy, mountainous or otherwise unusable. The district has diversified agro-ecological zones with the range from Dega to Kola. The district categorized in sub -humid tropical climate of bimodal rainfall pattern.

The average annual temperature is 13.8°, April is the hottest month of the year. At an average 12.7 °C December is the coldest month of the year. The average annual rainfall of the woreda is 1118 mm. Precipitation is the lowest in December, with an average of 12 mm. In July, the precipitation reaches its peak, with an average of 187 mm. it is located from 6°54′0″ to 7°7′45″ N and 38°31′33″ to 38°41′20″ E. The woreda has an altitude of 2430m above sea level (asl) (Kasahun, 2011, cited by Dinka 2017). For this research purpose, Ketar, Bosha-01 and Bosha-02 small scale irrigation schemes would be selected (data from werada). The werede border shared with four werede, Hitosa, Degeluna Tijo, Dodod Sire and Ziway Dugda.

Ketar Medium Scale Irrigation Scheme

Ketar irrigation scheme uses diverted water from Ketar River. Diversion of the scheme starts from the river which crosses the road taking from Asella to Munesa woreda. The river arises from the glaciated slopes of Mount Kaka and Mount Badda in the Arsi Zone. The river is generally steep and areas suitable for irrigation are few in number and very limited in extent with a watershed of 3400km2. It drains into Lake Ziway ('Kasahun, 2011', cited by Dinka, 2017).

Ketar medium scale irrigation scheme is located at about 25 km from Asella in Kebele so called Ketar Gennat, Hamsa Gasha, Abosara Alko and diverted from Ketar Rive . It has three stations Ketar-1, Ketar-2 and Ketar-3 (figure 3.1). The scheme was designed to irrigate around 446 ha of land. Different crops are grown in the scheme, potato being the major irrigated crop about 46 % or 212 ha. Other dominant crops include onion, cabbage, and shallot with 95, 53 and 32 ha areal coverage, respectively (wereda report and data, 2019).

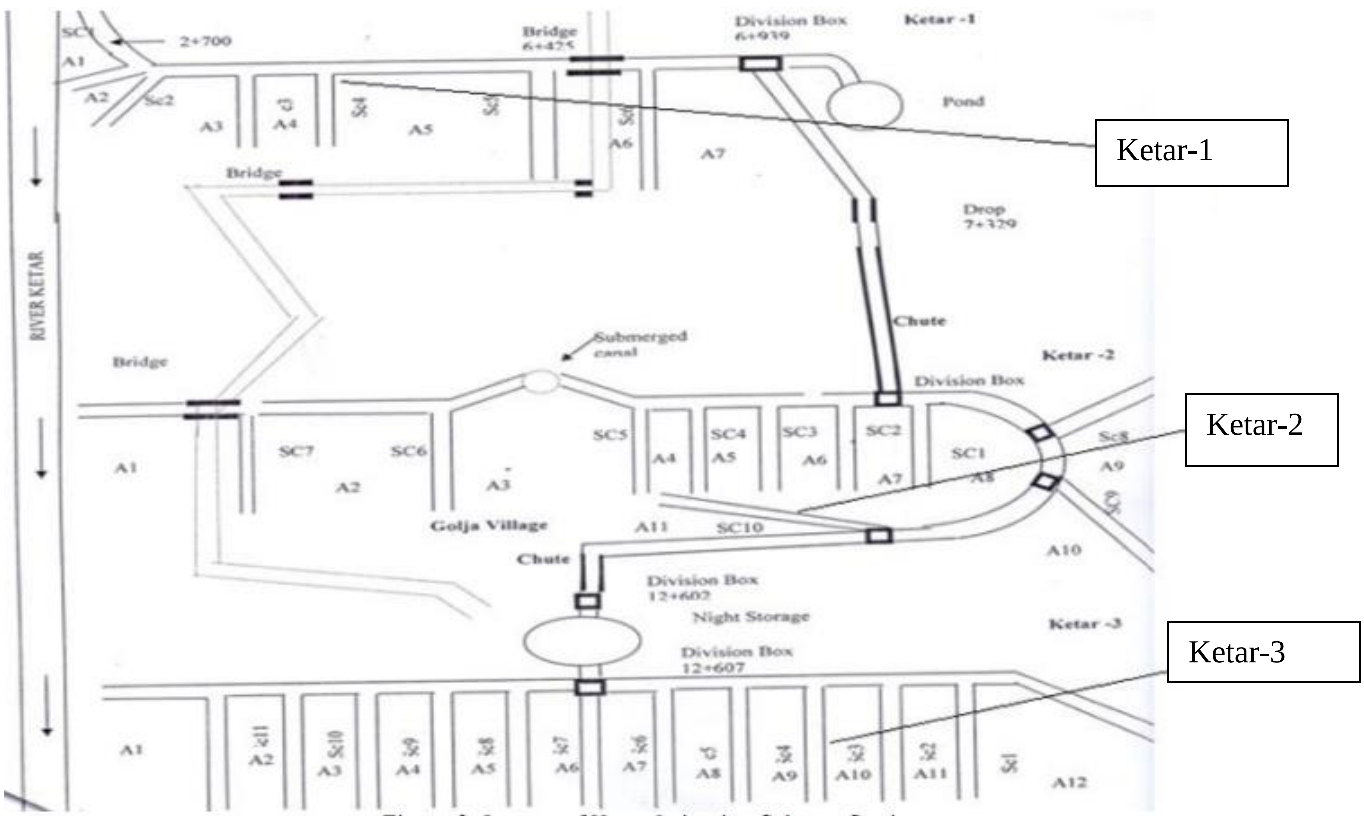

Figure 3.1 Ketar scheme layout (source: from Ketar rehabilitation document)

The scheme is composed of a simple intake structure with diversion constructed by stone masonry. Whereas, the main canal designed to carry a capacity of 805 l/s with the length of 13 km lined canal, 3.4 and 2.3 km of secondary and tertiary canals respectively. The scheme also comprises division boxes, road culverts, drainage, and other hydraulic structures.

3.1.2. Ziway Dugda District

The studied area Ziway Dugda district is found in Oromia Regional state under South east of Arsi zone. It is located 215km far from Addis Abba in the southeast direction. The werede border shared with four wereda, Hitosa, Ziway lake, Dodod Sire and Tiyo, The altitude of this woreda ranges from 1500 to 2300 meters above sea level and contains diversified agro-ecological zones with the range from Wina Dega to Kola (Google map). A survey of the land in this woreda shows that 46.3% is arable or cultivable, 6% pasture, 37.7% forest and the remaining 16% is considered swampy, mountainous. The only river in this district is Ketar and Chufa River. The district categorized in sub humid tropical climate of bimodal rainfall pattern. However the space-time distribution of rainfall is highly variable. For this research purpose, Arata chufa small scale irrigation scheme was selected.

Arata Chufa Small Scale Irrigation Scheme

Arata Chufa small scale irrigation scheme is a type of diversion system; which is located 30km far from Asella town in the way to west direction. The area has an average altitude of 1780 m.a.s.l. It is located in Arata PA (Figure 3.2). The irrigation scheme has total household beneficiaries of 340. The total command area is 100 ha. Crops which are dominantly grown are Onion, potato, head cabbage and Carrot.

The scheme is composed of a simple intake structure with diversion constructed by masonry. Whereas, the main canal designed to carry a capacity of 198.8 l/s with the length of 450 m masonry lined canal. The scheme also comprises division boxes, road culverts, drainage, and other hydraulic structures (Design Document).

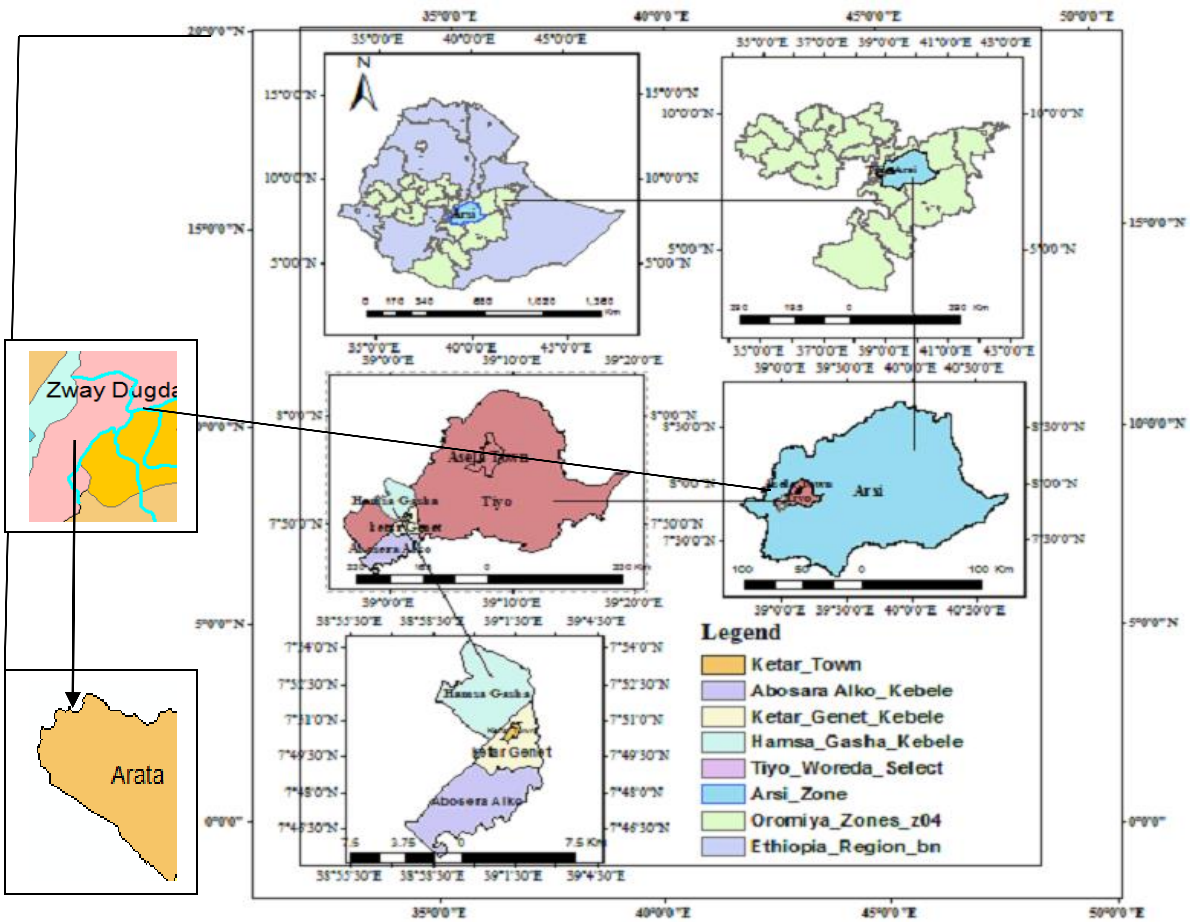

Figure 3.2. Location Map of Study Area

3.2. Field Layout and Crop Selection

The fields were selected for observations both along and across the slope of the command area. From each location along the scheme (upstream, midstream, and downstream), three farmer's plot from left, centre, and right across the slopes of the command area were selected with a total of 18 farmers' fields and the field assessment was undertaken to evaluate the irrigation application, storage and irrigation water losses of farmers at field level. The assumption behind the selection criteria of the farmers' fields were that first to increase the sample size and to check if there would be a tendency of the upstream users to over irrigate their crops while the tail users are facing in short supply of irrigation water.

The criteria for selection of crops were location (head, middle, and tail), their similarity with water management practices, crop grown and willingness of the farmers to collaborate. The most dominant crop covering the schemes were selected.

To evaluate the irrigation conveyance efficiency at field level, the sample was taken at 550 meter and 200 meter interval along the main canal for the long and short canal length respectively. 200 meter along secondary and tertiary canal for each scheme was taken.

3.3. Data Collection and Analysis

3.4.1. Data collection methods

The research was carried out during the irrigation season starting from March to June 2019 and September to November 2019. In this study, quantitative and qualitative primary and secondary data were collected to get answer for the research questions. For field data collection and measurement purposes, double ring infiltro-Meter, Auger, core sampler, tape meter, weight balance, partial flumes, floating material, CROPWAT 8.0 and GPS were used during the study period. Discharge was measured by floating method and using hydraulic structures at diversion head work, main canal and secondary canals of the four schemes and it was measured at field level by using Partial flume.

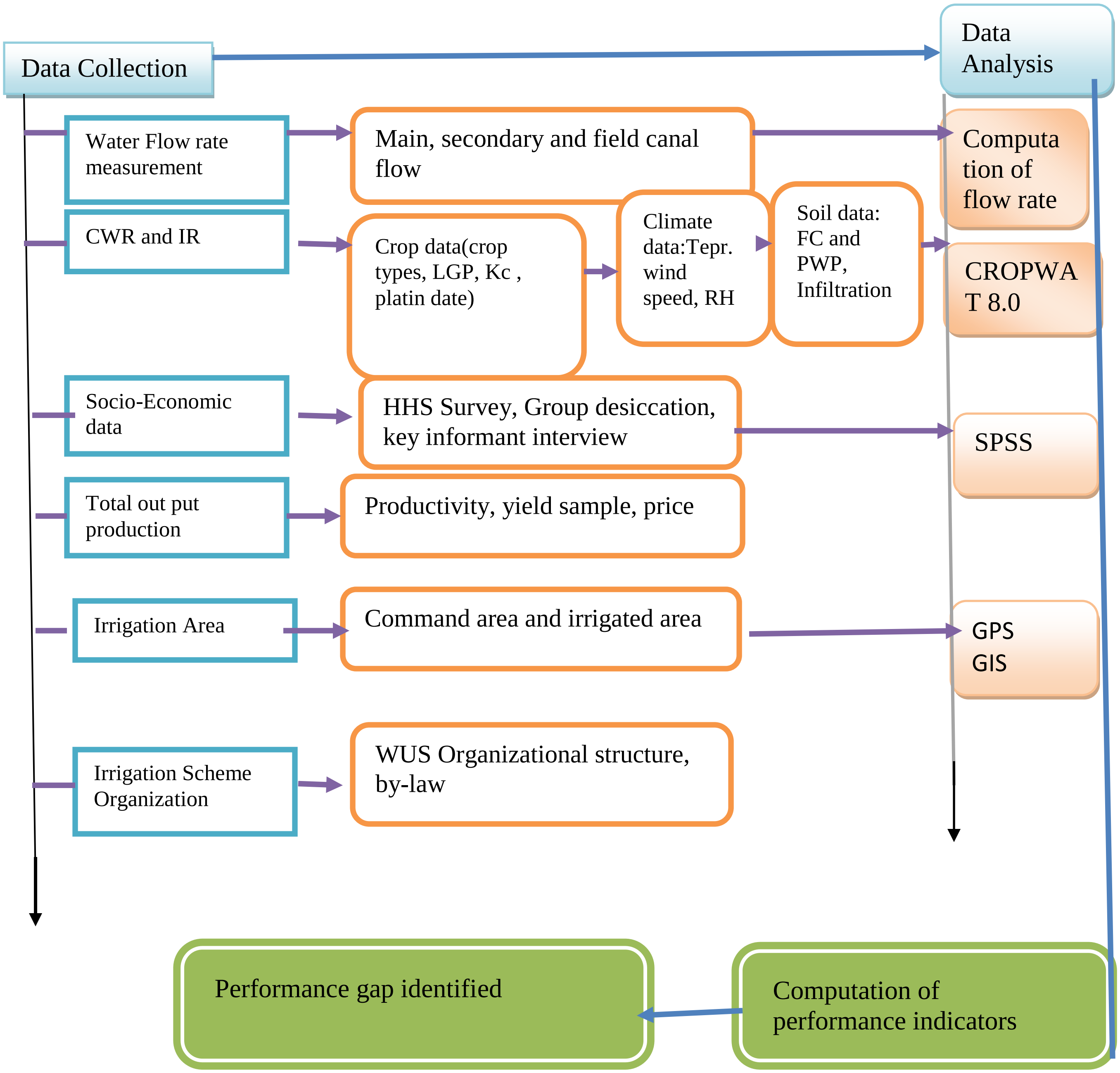

Figure 3.3: Flow chart of methodology used.

3.4.1.1. Primary data collection

Various types of primary data have been collected through formal and informal survey approaches. House hold surveys, key informant interviews with respective stakeholders and group discussions have been deeply practiced for cross comparison and wellbeing of information gathering and analysis. Field measurement including soil samples was collected for the determination different soil parameters and soil infiltration rate test was taken for all sites.

3.4.1.2. House hold survey and key informant interviews

Issues related to production systems, organizations and community level problems have been collected through key informant interview and focus group discussions. Key informant interview was conducted from chairman of WUA; Vice chairman of WUA; three water user leaders (WUL) at head, middle and tail of the scheme; district agricultural and rural development office irrigation expert; and Kebele's irrigation and plant science experts (DA's). Generally 14 questions were prepared and 56 respondents in Ketar, 42 in Arata, 36 in Bosha-01 and 34 in Bosha-02 have been interviewed.

3.4.1.3. Focus Group Discussion

Additionally group discussion has been hold with WUA committees; three selected water user group leaders at head, middle and tail of the scheme; nine water users were selected by stratified proportional random sampling from head, middle and tail of the scheme (females were included), Kebele agricultural development agents (DA's), kebele administrative head and Kebele's court head. For group discussion purpose generally 13 types of questions were prepared. The discussion was carried out with 21 in Ketar, 18 in Arata chufa, 16 in Bosha-01 and 12 in Bosha-02 participants for half day.

3.4.1.4. Observation

Functionality of irrigation schemes, structures design system, carrying capacity (actual), damage, condition of distribution structures, problem of flooding, erosion, siltation of canal, weed growth in the canal and on farm, water logging, siltation, total area proposed, ,irrigation practices and type of crop grown and other relevant data was observed at the field and photographs was taken as aiding tools. Grid coordinates was collected using GPS (Global Positioning System) for the purpose of to calculate area under irrigation. Field visit enables to visualize and identify the visible factors which affect the performance of the scheme.

3.4.1.5. Field measurement

I. Soil Sampling

Composite soil samples at 30cm and 60cm depths have been collected at each stratum for the determination of soil physical properties; soil texture, Field capacity (FC) and Permanent Wilting Point (PWP), the values have been computed through libratory working procedures. For the determination of soil textural class two composite soil samples at the specified depths have been taken at each stratum (head, middle and tail).

To determine the soil texture disturbed soil samples and for bulk density, moisture content at field capacity and permanent wilting point undisturbed soil samples were collected by core sampler and were taken to laboratory for analysis. Based on soil parameters of textural class, FC, PWP and the value of depletion fraction (P) obtained from FAO recommendations. Total of twelve potato grower and six onion grower farmers' plots, three from each station were selected

II. Water flow rate measurement using float method

To check conveyance efficiencies in the study area, the condition of infrastructure and the discharge rate at main, secondary and tertiary canals were measured. Points at measurement taken had regular and irregular shapes. For calculating area for regular canal shapes like trapezoidal and rectangular their respective formula were used. In the case of irregular shapes or earthen canals they were divided into partitions of small trapezoidal shapes across the canal and the total area were computed by their summation of each partition. Discharges were measured at necessary points. Measurements taken were at diversion weir and at primary, secondary and tertiary locations of the scheme.

III. Water flow rate measurement using partial flumes

To determine the flow rate at farm inlets measurements was taken by Flumes from sampled farmers. Totally eighteen farmer plots were selected purposively from farmers that was selected for questionnaire survey at each canal reaches (head, middle and tail) at four schemes. The partial Flumes that used for this study work has three inches (3''size) partial flumes. These are calibrated Partial flume to compute the application efficiencies, storage efficiency and water lose in irrigation.

3.4.1.6. Secondary Data Collection

Secondary data collected includes data which describe the original scheme and design command area and scheme management. The data collected from the secondary source include procurement of necessary documents and other useful written and published materials related to the scheme.

Information related to total irrigated area covered by the scheme, area irrigated per crop per season/year, crop types, cropping pattern, market price of crop (local), were gathered, information such as productivity per unit of irrigation water and environmental problems such as water logging and salinity were also gathered. The meteorological Long-term climatic data (maximum and minimum temperature, RH, sunshine hour, wind speed at 2 meter height from the earth surface of the irrigation schemes were collected from Chebi Meteorological Station and National Meteorology Agency was used for crop water requirement. Data which concerns about design and management of the scheme were collected from Tiyo Wereda Agricultural and Natural resource and Ziway Agricultural and Natural resource office.

3.4.2. Data Analysis Techniques

Data collected from key informant interviews, group discussions and observations were qualitatively analyzed, summarized and discussed using table. For data analysis and manipulation activities CROPWAT 8.0 software's and excel sheet was used. Finally the selected performance indicators were computed and data from different sources was triangulated to get reliable information. The data used were analyzed as follow:-

3.4.2.1. Soil parameter determination

i. Soil Texture

For textural analysis of the soil, disturbed soil samples were collected from each scheme at three locations along diagonal of the selected fields of each scheme (head, middle, and tail end) using soil auger with the depths 0-30cm, 30-60 cm. Hydrometer method was used for analyzing particle size distribution at Kulumsa agricultural research institute Laboratory and the textural class was assigned using USDA textural triangle (appendix figure 8).

ii. Soil Bulk Density

The soil bulk density (BD) was determined from undisturbed soil samples using a core sampler of size 5 cm internal diameter and 5 cm height. The soil sample was collected from 0-30 cm and 30-60 cm at three locations along the diagonal of each selected field and oven dried at 105 °C for 24 hours. The bulk density was determined using the following equation Hillel (2004):

$$BD = \frac{\mathrm{M\,s}}{\mathrm{Vtc}} \text{ --3.1}$$

where, BD = soil bulk density (gm/cm^3)

Ms = mass of dry soil (gm) and

Vtc = total volume of soil in the core sampler (cm^3)

iii. Field capacity, permanent wilting point and moisture content determination

In the 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 two days after irrigation were made by gravimetric method which involves collecting soil samples with auger, weighing the wet soil samples, removing the water by drying in an oven at 105 ^{0}C and reweighing the sample to determine the amount of water removed.

For every eighteen plots, soil samples were taken before irrigation and two days after irrigation from 0 - 30 cm and 30 – 60 cm depths per test pit. The oven dried soil samples with container and core were weighed again and recorded. Core sampler which has 5 cm diameter and 5cm height, whose volumes becomes 98.13 cm^3 was used. After the soil moisture sampler collected and oven dried, the moisture has been calculated as a percentage of dry weight of the soil sample (θ_m) using the following formula.

$$\theta_m = \frac{(Ww - Wd)}{Wd} * 100 \text{ --3.2}$$

Where: θ_m = soil moisture status in weight basis (%)

Ww= weight of fresh sample (g)

Wd= the weight of the dry soil sample (g),

The moisture content of soil samples were converted to the volumetric moisture content (θ_v) has been calculated using equation

$\theta_v = \theta_m$*Bsd --3.3

Where: θ_v = volumetric moisture content (%)

Bsd = specific grivet

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 base at field capacity and permanent wilting point (Allen *et al*., 1998):

TAW (mm) = 10 * (θFC – θPWP) *Rdz --3.4

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

θFC is moisture content at field capacity (%),

θPWP is the moisture content at permanent wilting capacity (%) and

Rdz is the root depth (m).

3.4.2.2. Determination of crop water and irrigation water requirement

Determination of 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 irrigated crops grown in the irrigation scheme was estimated using CROPWAT 8.0 windows computer program. The determination of the CWR by the model depends on the determination of the reference evapotranspiration value using the available climatic data. Data for major crops grown in the study areas including growing stages and stage lengths (days), crop coefficients (Kc), rooting depths (Rdz), depletion levels (P), yield response factors (Ky) and planting date were obtained from FAO guidelines (Allen *et al*., 1998). From ETo which has been determined at each growth stages ETc was computed as:

ETC=ETo ∗Kc--3.5

Where: ETc = crop evapotranspiration (mm/day)

ETo = reference crop evapotranspiration (mm/day) and

Kc = crop coefficient was taken from FAO irrigation and drainage (1992) and 56 (1998) papers

The irrigation water requirement (IR) was computed after estimation of effective rainfall by the CROPWAT model using the water budget equation.

IR = ETc - Peff ---3.6

Where: ETc is crop evapotranspiration (mm/season), and

Peff is effective rainfall (mm/season).

3.4.2.3. Irrigation scheduling

For determination of irrigation schedule of the irrigation schemes and to make comparison with the current irrigation practices; moisture content, field capacity, permanent wilting point, depletion fraction at each growing stage data were collected. Additionally farmer's irrigation practices were determined; such as irrigation methods, irrigation frequency and interval of irrigation, and application depths.

During the determination of the amount of water applied to the field, the average water flow rate to the farm inlet and respective time were recorded with the size of the fields being irrigated. The total volume of water applied to the field was obtained by multiplying the discharge rate with the inflow time. The depth of water applied to the field was obtained by dividing the total volume of water applied to the area irrigated.

The irrigation intervals of crops were determined procedurally through equations 3.7 and 3.8 (Michael, 2008). Finally the irrigation schedules of main crops at four irrigation schemes were determined using CROPWAT 8.0.

$\boldsymbol{I = \frac{RAW}{ETc}}$ ---3.7

RAW = TAW $*$ P --- 3.8

Where: RAM = readily available water (mm)

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

I = Irrigation interval [day]

TAW = is total available soil moisture (mm);

ETc = Evapotranspiration of the crop [mm/day]

3.4.2.4. Flow Measurement

Determination of flow velocity through main, secondary and tertiary canals was obtained by floating methods. Floating material was put on the upper end of the canal section and the time it took to reach the marked section of the same canal was registered. This test was replicated four times and the average time it took was taken to calculate the discharges. The average velocity and the rate of flow (discharge) were calculated by dividing the distance with the average time and by multiplying the cross sectional area with the average flow velocity, respectively.

The method consists of estimating the average flow velocity (V), and measuring the area of the cross-section, called the 'wetted cross-section' (A). The discharge (Q) can be calculated by the following formula:

$$Q = V * A \quad \text{--} 3.9$$

Where: Q = the Discharge in m^3/s;

V = the average flow Velocity in m/s;

A = the area in m^2 of the wetted cross-section.

To estimate the average flow velocity, the flow velocity of the water at the surface, the surface velocity, Vs, is first determined. The surface velocity is determined by measuring the time it takes for a floating object (lemon) to travel through a previously measured distance of 10 meters along the canal.

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

$$\boldsymbol{Vs = \frac{L}{t}} \quad \text{--} 3.10$$

Where:- Vs = the Surface Velocity in meters per second (m/s);

L = the distance in meters between points A and B; and

T = the Travel time in seconds between point A and B.

The surface velocity must be reduced in order to obtain the average velocity, because surface water flows faster than subsurface water. For most irrigation canals this reduction factor is about 0.85. The average velocity is therefore found from:

V = 0.85 Vs --3.11

Where: V = the Average Flow Velocity in m/s;

0.85 = a constant, the Reduction Factor; and

Vs = the surface velocity in m/s found from the previous calculation

Partial flume was designed and constructed at Asella Agricultural Engineering Research Center based on its standard dimension (Appendix figure 8). Before releasing water to flow through the flume its sitting was corrected by water level both along and across water flow. Then flow of water into field was measured using 3" (3 inch) size partial flume at the entrance of the water flow to the field. Irrigation was continuing until the farmers' thought that enough amount of water is applied to the field. When the irrigator completed irrigating the field, the average depth of irrigation water passing through the flume and the respective time were recorded for the sizes of field being irrigated. The discharge was computed using table (Appendix table 18) and equation (3.12):

$Q = C*H^n$ --3.12

For 3'' partial flume $Q = 0.1771H^{1.55}$

Where: Q = discharge through the flume (l/s)

C = discharge coefficient from rated tables

H = is water depth measured at one third from in late of converging,

C and *n* are constants to be determined for flume with three-inch throat from rated tables

3.4.3. Performance Indicators

3.4.3.1. Internal Indicators

For this study, three internal performance indicators were used in order to evaluate the internal system performance of each scheme, namely, conveyance efficiency, application efficiency, and water storage efficiency.

I. Conveyance Efficiency (Ec)

The conveyance efficiency was measured on the main canal by measuring discharges at two different points. The discharges were calculated from the velocities of the water flowing in the main, secondary and tertiary canal using floating materials. Discharge was measured at different locations over the length of the canal in order to calculate Ec at different sections.

The discharge measurement was conducted in the upper position (at the canal intake) of the main canal during the study period to determine the actual discharge of intakes in the scheme. The cross sectional area of the canal was also estimated by measuring the average depth and width of the same canal section.

The second measurement was taken at a fixed distance above the downstream end of the main canal. The same procedure was followed to that of the upper parts of the canal to estimate the discharge at the outlet (the downstream end) so that the amount of conveyance loss was known and the conveyance efficiency was determined. The measurements for both positions were taken four times.

Then continuity equation (Q = A x V) was used, where, Q is the discharge (m^3/sec), A, the cross sectional area of the canal (m2) and V, the average flow velocity (m/sec).

The conveyance efficiency was calculated by using equation (Bos et al 1994).

$$Ec = \frac{amuont\ of\ water\ delivered\ to\ farm}{amount\ of\ water\ diverted\ from\ source} * 100 \quad \text{---} 3.14$$

Where: Ec = conveyance efficiency (%),

the water delivered and diverted discharge in specified canal length in m^3/sec.

The overall conveyance efficiency of the main canal is the product of Ec calculated at different sections over the length of the canal. The overall conveyance efficiency of the schemes was computed using the following equation.

$$Ec = Em * Es * Et \text{--} 3.15$$

Where: Em = conveyance efficiency of the main canal (%),

Es = conveyance efficiency of secondary canal (%),

Et = conveyance efficiency of tertiary canal (%).

Losses in conveyance system were computed as:

Lc = $Qin - Qout$ ……………………………………………………………………..3.16

Where: Ec = conveyance efficiency (%)

Lc = conveyance loss (m^3/sec)

II. Application Efficiency (Ea)

The evaluation of the application efficiency was made on eighteen selected farmers' fields of four irrigation schemes. Water applied to the field was measured by installing 3″ partial flumes at entrance of selected farmer's field when fields were being irrigated. To determine the amount of water applied to the field, water depth passing through the flume to the field and its respective time intervals were recorded with the size of the field being irrigated.

Finally, the moisture content stored in the root zone was determined by a gravimetric method using equation (3.3). Application efficiency was computed as follows (Michael, 2008): $Ea = \frac{Ws}{Wd}$ *100 -- 3.17

Where: Ea = application efficiency

Ws = average depth water stored in the root zone of the plant

Wd = average water delivered to the field (water depth applied to the field)

III. Storage Efficiency (Es)

To determine the water stored in the soil root zone of each field, soil samples were collected from a different location within the field at a depth of the 0-30 cm and 30-60 cm before and after each irrigation event. The moisture content was determined using the gravimetric method.

The storage efficiency was obtained by the relationship given below (Roger, 1997).

$Es = \frac{Ws}{Wn}$ *100 --3.18

Where: Es = storage efficiency (%)

Ws = water stored in the root zone during irrigation (mm)

Wn = water needed in the root zone prior to irrigation (mm)

IV. Deep Percolation Ratio

The Furrow that practiced in Arata chufa schemes are closed-end. But, furrow that practiced in Ketar irrigation scheme open- end. Therefore, runoff ratio neglected and the evaporation from the soil also neglected because it is only a short period after irrigation. The loss of irrigation water beyond the root zone is only through deep percolation. Therefore, deep percolation ratio was calculated by using the following equation (Henok, 2017)

$$DPR = 100 - Ea - RR \text{--- } 3.19$$

Where: DPR = Deep percolation ratio (%),

Ea = application efficiency (%) and

RR = runoff ratio

Then after, the overall scheme efficiency calculated as the product of conveyance and application efficiency. It was computed using the following formula (FAO, 1993):

$$Eo = Ec * Ea \text{---}3.20$$

Where: Eo = overall scheme efficiency (%)

Ec = conveyance efficiency (%)

Ea = application efficiency (%)

3.4.3.2. External Indicators

In this part two land productivity and four water productivity indicator was used in order to evaluate the external system performance of each schemes like output per cropped area, output per unit command area, output per unit water supply, output per unit water consumed production, relative irrigation supply and relative water supply such data crop production, irrigable-cropped area and command area were collected from the two District Agricultural offices. Total production (Birr) for the year 2019 was calculated by using local farm price and yield production of the four studied Irrigation Scheme. The following equations were used to compute some agricultural output indicators (Molden *et al*., 1998).

A) Land productivity

I. Output per unit irrigated area (OPUIA)

It is computed as the total value of production per harvested area in the irrigation seasons. The harvested Irrigated area includes the areas that were irrigated in the irrigation seasons

$$\text{OPUIA} = \frac{\text{value of production} \quad (\text{Birr})}{\text{irrigated cropped area} \quad (\text{ha})} \text{--3.21}$$

II. Output per unit command area (OPUCA)

This indicator quantifies the value of production that obtained per unit command irrigable area. Command area is the nominal or design area to be irrigated. High value result shows there is good intensive irrigation. While small values are not pertinent from land productivity point of view; less intensity of irrigation could not increase the production amount per unit of land

$$\text{OPUCA} = \frac{\text{value of production} \quad (\text{Birr})}{\text{commandarea} \quad (\text{ha})} \text{--------------------------------------3.22}$$

B) Water productivity

I. Output per unit irrigation water supply (OPUIS)

It quantifies the value of production per unit delivered irrigation water to the head of farm inlets in the irrigation seasons. It is the net irrigation water delivered to the farm and it does not include losses in conveyance systems. It is a useful comparative indicator because it addresses output per drop of irrigation water actually delivered to the user. A lower value of this indicator indicates there is inefficient water use in the irrigation system or specifically at farm level.

$$\text{OPUIS} = \frac{\text{value of production} \quad (\text{Birr})}{\text{volume of irrigation diverted} \quad (\text{m3})} \text{--3.23}$$

II. Output per unit water consumed (OPUWC)

$$\text{OPUWC} = \frac{\text{value of production} \quad (\text{Birr})}{\text{volume of water Consumed} \quad (\text{m3})} \text{--------------------------------3.24}$$

III. Relative water supply (RWS) and relative irrigation supply (RIS)

As Molden et al.(1998) cited, relative water supply as presented by levine (1982) and relative irrigation supply are used as the basic water supply indicators:

Relative water supply (RWS) = $\frac{Total\ water\ supply}{\text{Crop water demand}}$ ---3.25

Relative irrigation supply (RIS) = = $\frac{\text{Total irrigation Supply}}{\text{Irrigation demand}}$ --------------------------------------3.26

Where:

Total water supply = surface water diversion, Crop demand = potential crop ET and Irrigation demand = the crop ET less effective rain fall.

Both RWS and RIS relate supply to demand and give some indication as the condition of water abundance or scarcity and how tightly supply and demand are matched.

3.4.3.3. Physical Indicators

The selected indicator used for evaluation of physical performance was irrigation ratio and Sustainability of irrigated area, which can be expressed as the follows (Molden *et al*., 199; Shenkut, 2015).

I. Irrigation Ratio (IR)

To quantify the level of utilization of the potential irrigable area for irrigated agriculture for a particular production time period. The irrigated area during the study period and the irrigable potential of each scheme were collected from the two Tiyo and Ziway Dugda district Agricultural Office.

Irrigation ratio is the ratio of currently irrigated area to the command area (Bos et al., 1994).

IR= = $\frac{\text{Irrigated crop area (ha)}}{\text{Command area (ha)}}$ ---3.27

Where: Irrigated area = irrigated area in the irrigation season (ha)

Command area= the design (nominal) irrigable area (ha).

II. Sustainability of Irrigated Area (SIA)

Sustainability of irrigated area is the ratio of currently irrigable area to initially irrigated area. This important indicator mainly used to observe the status of the irrigation systems either contracted or expanded. If the computed value is small or less than 1 it shows the irrigable area is contracted and if it is large i.e. greater than one, it shows the irrigable area is expanded from the designed irrigable area through including nearby farm areas.

The currently irrigable area and nominal irrigated area of all schemes were collected from the two Tiyo and Ziway Dugda district Agricultural office. Sustainability of irrigated area were computed by using the following equation (Solomon, 2016; Molden *et al*., 1998)

$$SIA = \frac{\text{Current irrigable area (ha)}}{\text{initially irrigated area (ha)}} \quad \text{--3.28}$$

Where: Current irrigable area = the area currently irrigated (ha)

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

3.4.3.4. Organizational indicators

Organizational objectives, functions and structures of Water user association's (WUAs were assessed. Under this organizational establishment, roles and functions, organizational structure and level of management starting from users to general assembly level were assessed. The responsibility at each level was identified. Beneficiary's degree of participations in operation and maintenance activities and number of rounds for canal cleaning in the production year also assessed. Functionality of bylaws and internal rules and regulations and legal enforcement status was identified.

Water use fee amounts for members and non-members, water allocation at each organizational level, way of water allocation and gaps was clarified. Types of conflicts, causes of conflicts and conflict management experiences were assessed at each irrigation schemes. Finally the organizational structures were indicated in map.

4. RESULTS AND DISCUSSION

4.1. Soil Data Analysis Results

Soil samples were taken at depth of (0-30 and 30-60cm) to investigate the physical a properties of the irrigation schemes. From the sampled soil texture, field capacity (FC), permanent wilting point (PWP) were analyzed and the summarized results are presented and discussed as follows.

I. Soil textural class

The soil textural class of both irrigation schemes was determined based on the particle size distribution through using USDA Soil Textural Triangle method (Appendix Figure 7). As indicated in appendix table 28 and summarized in table 4.1; the soil texture distribution was slightly varied at Ketar irrigation scheme. Clay Loam soil type was found in the head and tail of the scheme; while the dominant soil type in the middle of the scheme was clay soil type. The result of the soil analysis from the experimental site showed that the composition of sand, silt and clay percentages were in the range of 35.5%, 25.2% and 29%, respectively.

In Arata chufa irrigation scheme clay loam soil type was more dominant in head and tail of the scheme but clay was dominant in the middle part of the scheme. The result of the soil analysis from the experimental site showed that the composition of sand, silt and clay percentages were in the range of 32.5%, 30% and 25.5%, respectively. The dominant percent particle size distribution for selected irrigation scheme was classified as clay loam.

Table 4.1: Soil textural classes of the irrigation schemes

Irrigation scheme	Field reaches	Soil depth (cm)	Particle size (%)			soil texture
			clay	silt	sand	
Ketar	average	0-30	33	28	30	clay loam
		30-60	38	22	28	clay loam
		Scheme average	35.5	25	29	clay loam
Areta cufa	average	0-30	30	32	26	clay loam
		30-60	35	28	25	clay loam
		Scheme average	32.5	30	25.5	Clay loam

II. Soil Moisture Content and Bulk Density

From soil samples collected at depth of 0-30 and 30-60 cm, average soil moisture contain (equation. 3.2 and 3.3) were found as 34.35 and 30.43 respectively for Ketar and Arata. Bulk densities (equation 3.1) were found as 1.11, 1.10 g/cm^3 for Ketar and Arata respectively (Table 4.2).

Table 4.2. Average Soil Moisture and Bulk Density of irrigation Schemes

schemes	weight of moist soil (gm)	Oven dried soil weight (gm)	weight difference (water weight)	Volume of core sampler volume cm3	Bulk density (g/cm3)	Moisture content in dry weight base (W) %	Volumetric moisture content %
Ketar	142.37	108.66	33.71	98.13	1.1073	27.25	34.35
Arata	137.98	108.12	29.86	98.13	1.1018	27.62	30.43

III. Field capacity, permanent wilting point and Total Available Water (TAW)

For determination of soil field capacity and permanent wilting point twelve samples from each station and totally 36 samples were collected and taken to Pressure plate Apparatus (at kulumsa agricultural research center). The soil moisture content at field capacity (FC) and permanent wilting point (PWP) were determined after soil samples were saturated for one day (24hrs) using the pressure plate apparatus. Field capacity was determined by exerting a pressure of 0.33 bars and permanent wilting point was determined by exerting a pressure of 15 bars until no change in moisture was observed. The FC and PWP values were further used to determine total available water (TAW) (equation 3.4)

Table 4.3 Computation of Average Total Available Water (TAW) of irrigation scheme

schemes	Ketar		Arata Cufa	
Station	0-30	30-60	0-30	30-60
FC(%w/w)	34.3	33	31	33
PWP(%w/w)	21.6	21	21.6	20
Bulk Density	1.1	1.12	1.08	1.12
Depth(mm)	300	300	300	300
TAW(mm)	41.91	40.32	30.45	43.68
TAW(mm/m)	139.7	134.4	101.52	145.6
Average TAW mm/m	137.05		123.56	

Where; FC= field capacity (vol. %), PWP= permanent wilting point (vol. %),TAW= total available water in the root zone (mm)

From Table 4.3 the observed average soil moisture content at FC was varied within a narrow range of 28.13 – 34.3 on weight basis. The top 0-30 cm thick soil surface was having larger field capacity (FC) while 30-60 cm soil layers were having lower FC values on weight basis. The observed soil moisture content at PWP was also showed a variation with depth in a narrow range of 15.74 – 21.6 % on weight basis. The average field capacity and permanent wilting point of the soil was found to be 33.65, 32.5 % and 21.3, 20.8 % on weight basis at ketar and Arata chufa respectively

The total available water (TAW) that is the amount of water that a crop can extract from its root zone was related to variation in FC and PWP. As a result, high value of TAW was found in the soil depth of 30-60 cm; whereas the lower values were observed at 0-30 cm soil depth. Average total available water (TAW) for Ketar and Arata chufa were found as 137.05, 123.56mm respectively (Table 4.3) considering maximum effective root depth of potatoes, onion and cabbage taken as 600mm, 500mm, 500mm respectively. In Average the moisture holding capacity of Ketar soil was better than Arata.

IV. Soil infiltration rate

The amount of infiltration rate and incremental infiltration rate can be accomplished by using the apparatus double ring infiltrometer whose diameter 30-60cm & height 60cm. One side of the ring have a cutting edge so that it will get-up-and-go inside the soil surface easily without any damage to the soil or to the cylinder. Then the inner ring and outer ring was filled with water at the same time. At a time interval of 5 minute and 10 minute measure the drop of water inside the inner ring only. The measurement was continual until and unless a fixed rate of infiltration was achieved.

The data collected from the field using double ring infiltrometer on infiltration rate was used to generate infiltration rates of 2cm/hr and 0.2cm/hr after 5.454hrs and 6.46 hrs of test at field conditions; were computed in Ketar and Arata SSI schemes respectively. The observed test values are indicated in appendix Table 5.

The observed infiltration rates of the above soil textural classes were greater than the recommended ranges. The reasons might be related to the borrowing of soil profile but in general couldn't capture the exact problems for low and high infiltration rates. As a result it is better to use the average recommended values for inputs in CROPWAT model, i.e. 0.75 cm/hr for clay loam (FAO, 2011). Hence the textural class and the basic infiltration rate agree on clay loam of the soil (figure 4.1).

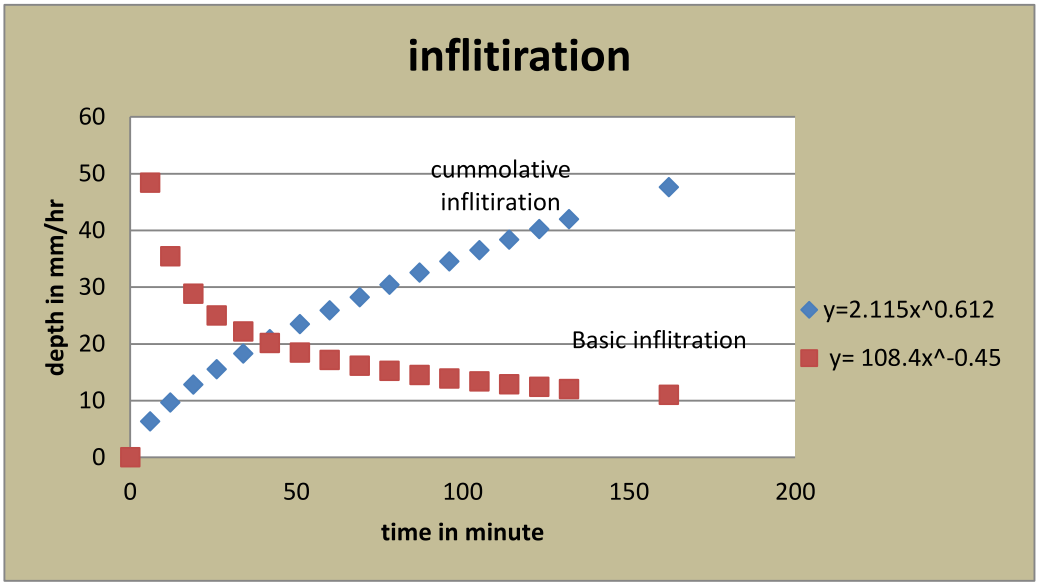

Fig. 4.1 Basic and Cumulative infiltration of the clay loam textural of the studied schemes

4.2. Crop Water Requirements and Irrigation Requirements

Necessary parameters, like minimum and maximum temperature, relative humidity, wind speed and daily sunshine hour of the study area were collected from Chebi Meteorological Station, which is nearby to the study area and National Meteorological Agency (Appendix Table 1)

Furthermore, Description of crop characteristics; i.e length of growing period (LGP) Crop coefficient (Kc) of growing period, maximum root depth (m) growth stage and allowable soil moisture depletion fraction values were adopted from FAO Irrigation & Drainage paper 24 and 56, (Appendix table 2). Then using CROPWAT 8.0 window computer program; calculate reference Evapotranspiration (ETo), crop water requirement and irrigation requirement.

4.2.1. Reference Evapotranspiration (ETO)

By using CROPWAT software the ETO of all months in the study area was ranging from 3.53 to 4.58 mm/day by multiplying with the day in each month 105.9 mm/month to 137.4 mm/month. Minimum ETO value was observed in December and maximum in April as shown in Appendixes Table 3 and summered in table 4.4.

The effective rainfall value for all months also ranges between 12.7mm and 154 mm; the maximum average monthly effective rain fall was observed in July while the minimum was observed in January.

Table 4.4 Average monthly ER and ETO of the study area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Augt	Sept	Oct	Nov	Dec	average
ETO(mm)	3.79	4.26	4.48	4.58	4.42	4.13	3.65	3.48	3.7	3.72	3.8	3.53	3.96
ER(mm)	12.7	24.9	55	48.5	47.7	102	154	154	81.9	70.5	17.5	8.9	776.8

4.2.2. Crop water requirement (CWR)

There are different crop types which are cultivated in Ketar and Arata chufa irrigation scheme. Those crops have different crop water requirement. The crop water requirement (CWR) of each crop was estimated for one irrigation season (from Febrary to June 2019) using CROPWAT 8.0 software program. The total crop water requirement results are summarized below in Table 4.5 and 4.6.

Table 4.5 Average monthly crop water requirement of cultivated crops in the schemes

month	CWR(mm/season)								Monthly Total (mm)
	Beet	Cabbage	Shallot	Potato	Onion	Pepper	Tomato	Carrot	
Feb	61.5	61.3	62.9	61.9	62.9	30.9	39.4	61.5	442.3
Mar	118.9	111.7	128.4	97	128.4	93.1	93.3	118.8	889.6
Apr	134.1	134.4	134.4	144.9	134.4	134.3	145.4	134.2	1096.1
May	49.2	130.7	100.2	140.5	63.9	129.6	134.6	49.1	797.8
Jun	0	22.5	0	19.1	0	21.5	19.6	0	82.7
Average	363.7	460.6	425.9	503.4	389.6	409.4	432.3	363.6	669.7

Multiplying the result from CROPWAT by the area covered by each crop type the total crop water requirement in flow form for the four irrigation schemes are summarized in Table 4.6.

Table 4.6 Average Crop water requirement for the four irrigation schemes (m^3/sec)

		crop water requirement (m3/sec)								
scheme	month	beet	cabbage	shallot	potato	onion	peppar	tomato	carrot	total
Ketar	Feb	0.006	0.038	0.0233	0.054	0.054	0.0002	0.014	0.0135	0.205
	March	0.012	0.07	0.0476	0.192	0.192	0.0005	0.033	0.0261	0.573
	Aprl	0.014	0.084	0.0498	0.361	0.361	0.0008	0.052	0.0295	0.951
	May	0.005	0.082	0.0371	0.35	0.35	0.0008	0.048	0.0108	0.883
	Jun	0.038	0.014	0	0.048	0.048	0.0001	0.007	0	0.154
	average	0.038	0.288	0.1577	1.004	1.004	0.0024	0.155	0.08	0.55
Arata	feb	0.001	0.009	0.0066	0.004	0.026	0.0011	0.008	0.0036	0.058
	march	0.002	0.016	0.0134	0.013	0.054	0.0032	0.018	0.0069	0.125
	Aprl	0.002	0.019	0.014	0.024	0.056	0.0047	0.029	0.0078	0.156
	May	0.001	0.018	0.0104	0.024	0.027	0.0045	0.026	0.0028	0.113
	Jun	0.005	0.003	0	0.003	0	0.0007	0.004	0	0.016
	average	0.005	0.064	0.0444	0.068	0.162	0.0142	0.085	0.021	0.093

As shown in Table 4.5 and 4.6, the total monthly crop water requirement has been fluctuating; higher from April (1096.1 mm/season) and relatively minimum in May (82 mm/season). The result displays that the crop water requirement is very high during the dry season and low during wet (rainy) season, therefore crops grown in the dry season needs more water than those grown during the rainy season and the stage of the crop is the other reason.

The total water requirement in the study area fluctuated from 363.6 to 503.4 mm/season during the growing season as shown in (Table 4.5). The lowest water requirement of the irrigated area is recorded for carrot (363.6 mm/season) and the higher requirement for potato (503.4 mm/season). This indicates that the crop water requirement is higher for crops which have longer growing period than for those which have shorter growing period.

4.2.3. Irrigation water requirement

The scheme irrigation requirement was calculated with CROPWAT 8.0 model using the climate data, cropping pattern, planting dates, and area coverage of individual crop for the cropping season. It was estimated based on ETc, the recorded rainfall and effective rainfall. The effective rainfall is derived from observed rainfall. Therefore irrigation water requirement was calculated from the difference between the total water requirement and effective rainfall (Table 4.7).

Table 4.7 Monthly average irrigation water requirement (mm/season)

month	IR(mm/season)								monthly Total
	Beet	Cabbage	Shallot	Potato	Onion	Pepper	Tomato	carrot	
Feb	40.3	40.1	40.7	40.7	41.7	9.7	18.2	40.7	272.1
Mar	64	56.9	74.4	65.1	71.5	38.2	39.4	74.4	453.9
Apr	87.7	86.7	83.9	99.5	83	87.8	96.9	83.9	709.4
May	32.2	84.1	53.9	92.7	40.5	82	88.3	53.9	527.6
Jun	0	5.7	0	4.3	0	4.7	2.8	0	17.5
Average	224.2	253.5	252.9	232.3	236.7	242.4	255.6	252.9	406.1

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 4.8

Table 4.8 Average irrigation water requirement for the four irrigation schemes (m^3/sec)

		irrigation requirrement m3/sec								
scheme	month	beet	cabbage	shallot	potato	onion	peppar	tomato	carrot	total
Ketar	Feb	0.004	0.025	0.015	0.002	0.045	6E-04	0.0065	0.009	0.107
	March	0.007	0.036	0.028	0.062	0.078	0.002	0.0141	0.014	0.241
	Aprl	0.009	0.054	0.031	0.248	0.09	0.005	0.0348	0.019	0.491
	May	0.003	0.053	0.02	0.231	0.044	0.005	0.0317	0.007	0.394
	Jun	0	0.004	0	0.011	0	0.001	0.001	0	0.016
	average	0.023	0.171	0.094	0.553	0.258	0.013	0.0881	0.049	0.25
Arata	Feb	0.006	0.006	0.004	0.001	0.017	0.001	0.0036	0.002	0.039
	March	0.009	0.008	0.008	0.004	0.03	0.001	0.0078	0.004	0.072
	Aprl	0.013	0.012	0.009	0.017	0.035	0.003	0.0191	0.005	0.112
	May	0.005	0.012	0.006	0.016	0.017	0.003	0.0174	0.002	0.076
	Jun	0	8E-04	0	0.001	0	0.001	0.0006	0	0.002
	average	0.032	0.038	0.026	0.037	0.099	0.008	0.0483	0.013	0.06

As shown in Table 4.7 and 4.8, the CROPWAT model simulated results shows that irrigation water requirement in the system was varying from 17.5 mm/season to 709.4 mm/season. The highest irrigation requirement was recorded in April and the lowest was recorded in June. This is because of due to the stage of the crops; crops need maximum water at mid stage. The total irrigation requirement of each crop varies from 255 mm/season to 222.4 mm/season. The highest irrigation water requirement was recorded in Tomato and the lowest was in beet root. It was happened because of beet root was having a small command area and short growth length compared to Tomato crop.

4.3. Water Flow Rate Measurement

It was quite difficult to measure water flow rates continuously from intake to farm inlets; because there was flow fluctuation, the farmer uses rotational scheduling systems, and sometimes there were water abstractions in the upstream illegal water users, and absence of reliable and functional flow control systems at some division boxes.

a) Canal water measurement

The discharge in a canal can be measured with floating method. The method consists of estimating the average flow velocity (V), measuring the area of the cross-section called the wetted cross-section (A) and the discharge (Q) can be calculated using 3.9, 3.10 and 3.11. The average velocity and discharge was calculated (appendix 6). In addition using measuring structures in ketar irrigation schemes

b) Field water measurement

To determine the amount of water applied by the irrigators to the field during an irrigation event, three inches (3’’) Partial flumes were installed at the entrance of test plot. Frequent readings were taken when the farmers irrigate the test plot. The discharge 3.02 L/sec at ketar and 2.82L/sec at Arata was computed (Appendix table 7) using equation (3.12) and from standard table (Appendix table 8).

4.4. Performance evaluation

4.4.1. Internal performance

4.4.1.1. Determination of irrigation Efficiency

I. Conveyance efficiency

The average main canal and tertiary canal conveyance efficiency of the scheme was measured as method described in Section 3 and presented in Tables 4.9 and Appendix Tables 10. By using mean velocity method discharge measured at diversion head main canal of Ketar and Arata chufa main canal were found as 0.554 and 0.192m^3/sec, respectively. Conveyance efficiencies were found as 50.9 and 71 % at Ketar and Arata chufa respectively (Table 4.9).

The Table related to conveyance efficiency indicates that there was seepage loss of irrigation water. As stated by FAO, (1989), for earthen canal length >2000m constructed on clay soil its conveyance efficiency would be 80% where as 95% for lined canal. From that result it is concluded that conveyance efficiency of the two schemes was poor. The main reasons were seepages and over flow in unlined tertiary canal, and seepages due to high siltation by soil and weeds in canals.

The major constraints for higher conveyance losses observed were:

- Canals have been silted with weeds and soils
- Canals were crack and broken due to long aged,
- The canals had small cross sectional area that leads to over flow,
- Sides and beds have been greatly damaged by scouring water due to steep bed slope and drop structures.
- Non-functional flow controlling structures.

II. Application efficiency

Average application efficiency of the scheme indicated that, it was in range of 73% and 70%, Ketar and Arata respectively (Table 4. 9) and appendix Table 13. According to FAO (1989), application efficiency for surface irrigation is 68%. Based on this Arata chuf and Ketar were efficient.

III. Water storage efficiency

From data collected and mean taken at two depths, namely 0-30 and 30-60 cm and using (equ. 3.19) average water storage efficiency (Es) were 89.84%, 87.14%, for Ketar and Arata chufa, respectively (Appendix table 13 and Table 4.9).That showed as farmers were using excess water, where as farmers in down steam facing deficiency of water even some times soil moisture content become less than field capacity especially at ketar and Arata chufa. According to Michael (2008), the importance of determining storage efficiency is that, when water supplies are limited or when excessive time is required to secure adequate penetration of water into the soil.

Table 4. 9. Summary of irrigation performance indicators

Efficiency parameters Scheme	Conveyance Efficiency (%)	Storage efficiency (%)	Application Efficiency (%)	Runoff Ratio (RR) (%)	Deep Percolation Fraction(DPF) (%)
Ketar	50.9	89.84	73	14.75	12.25
Arata	71	87.14	70	-	30

4.4.1.2. Water losses

a) Runoff Ratio

From measurements taken by Partial flume, average runoff ratio were 14.75 % for Ketar, Arata chufa are closed end furrow (Table 4.9). This result indicates that the schemes had more runoff loss than deep percolation because the soil type was clay loam (fig. 4.2)

If this water is re-used it can represent a significant supplemental supply compared with allowing the runoff to leave the farm. Generally, a common collector ditch can be used across the bottom of the field to channel the water into the headland facilities of a down slope field, or into a small pond for storage and later use. In case of the study area on which this research was conducted, there no such practice to reuse that runoff.

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 by digging traditional drainage ditches. Hence, it was an implication of over irrigation which is resulted in water logging problem

Figure 4.2 Runoff tail of furrow during irrigation at ketar

b) Deep percolation fraction (DPF)

Average results of deep percolation fraction for schemes were 12.25% and 30% at Ketar, and Arata chufa respectively (Table 4.9). This indicates since the soil of the study area was clay and clay loam, its deep percolation was lower than runoff because there was lateral movement in addition to vertical flow of water in such type of soil.

In general common losses observed at study site was seepage, none functional flow control gates, unauthorized water turnouts (breaching of main canals that leads leakage) and illegal water abstractions contributed for high water losses or low conveyance efficiencies at irrigation schemes. These losses affect the equity of water distribution throughout the systems; particularly the tail users did not get their equitable share within the required time at ketar and Arata chufa.

4.4.1.3. Overall Efficiency

The overall efficiency of Ketar, Areta irrigation schemes (equation.3.20) were 37% and 49.7% respectively (Table 4.10). This indicates that both schemes were performing with poor efficiency. Poor efficiency for Areta irrigation scheme was due to its poor application efficiency. On the other hand, scheme conveyance efficiency had a great share for its poor efficiency of Ketar irrigation scheme. Both schemes overall efficiency was nearly similar with the overall efficiency of Dodicha irrigation scheme, which is 38.6% as reported by Worku (2013).

Table 4. 10. Overall scheme efficiency of the schemes

	Scheme efficiency (%)	
Internal indicator	Arata	Ketar
Conveyance Efficiency	71	50.9
Application efficiency	70	73
Storage efficiency	87.14	89.84
Run off Ration	0	14.75
Deep percolation ratio	30.11	12.4
Overall Scheme efficiency	49.7	37

Source : field measurement

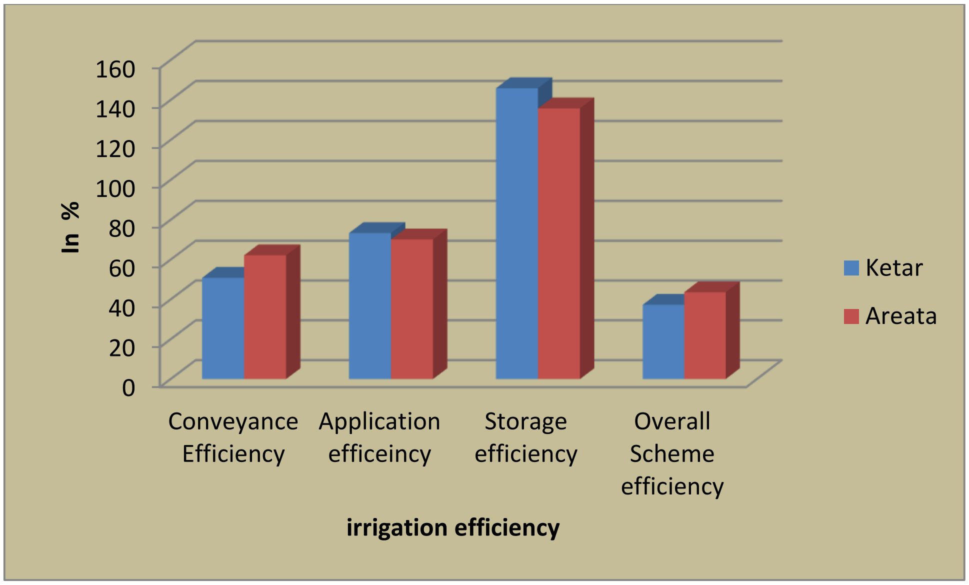

Figure 4.3. Irrigation efficiency of the study schemes

From the figure 4.3 Arata chufa efficiency is high this is due to short conveyance systems than Ketar. At Arata chufa high conveyance efficiency due to conveyance system was maintained by WUA every month than Ketar scheme. As a result of relatively more lined and better structural and canal effectiveness with more water fee collected to maintain canal and canal structure. Likewise conveyance efficiency of ketar is lower because of structural and canal effectiveness followed by length of unlined canal. But relatively more water fee which is not enough to improve scheme structures because it require more budget.

From Figure 4.3 application efficiency and storage efficiency relatively higher at ketar irrigation scheme as a result of more furrow length and stream size on clay loam soil at ketar irrigation scheme. Short furrow length on clay loam at Arata has lower application and storage efficiency. Similarly good application efficiency result in good storage efficiency as seen on figure 4.3.

4.4.2. External performance indicators

Under this comparison land and water productivity levels and major constraints were analyzed. These indicate performance indicator that is associated with the productivity. The major of such performance indicators includes; Output per unit irrigated cropped area

(OPUIA), Output per unit of command area (OPUCA), Output per unit irrigation water supply (OPUWS), Output per unit irrigation water delivered (OPUIWD), relative irrigation supply (RIS) and relative water supply (RWS).

The irrigated crop area during the study year was 456.5 ha and 86 ha at Ketar and Areta irrigation scheme respectively. Whereas, the designed area was 441 ha and 100 ha. The total production value of the scheme was 63,651,390 Birr and 19,532,655 Birr at ketar and Arata irrigation respectively (Table 4.11)

Table 4. 11 Crop yields and output production values for ketar SSI and Arata Chufa scheme for the season

Crop	Ketar IS					Arata IS				
	Area ha	Yield (Qt/ha)	Yield (Qt)	Average price (birr/Q)	Total income (Birr)	Area ha	Yield (Qt/ha)	Yield (Qt)	Average price (birr/Q)	Total income (Birr)
potato	212.8	291	61910	730	23084790	14.75	280	4130	700	2891000
onion	95.25	332	31623	890	9380600	26	335	8710	900	7839000
tomato	31	340	10540	840	12524400	15	350	5250	860	4515000
cabbage	53.25	280	14910	500	13500	12	300	3600	550	1980000
pepper	0.5	54	27	700	1547000	3	56	168	760	127680
carrot	8.5	260	2210	650	4604600	5	260	1300	670	871000
Shallot	32.2	220	7084	500	369000	9	225	2025	550	1113750
gralic	9	82	738	2000	9900000	0.75	79	59.25	2100	124425
kale	11	450	4950	450	2227500	0.5	354	177	400	70800
Total	453.5		133992		63651390	86		25419		19532655

After measuring the discharge at various working irrigation schemes, the average discharge was estimated to be 0.548m3/sec, 0.192m3/sec, at Ketar and Arata respectively. This discharge was used to estimate the volume of water diverted (V=Q*T) in these season was:

Ketar Scheme: 0.548*125*24*60*60 = 5,918,400m^3, Arata scheme: 0.192*125*24*60*60 = 2,071,861m^3(Table 4.12). Their CWR and irrigation requirement was calculated using CROPWAT 8.0 in section 4.2.2 and 4.2.3.

Then, the net crop water requirement and the net irrigation requirement are computed for each growing season. The outcomes were the total net crop demand for each irrigation scheme is CWR_{crop1} *($Area_{crop1}$/$Area_{total}$) + CWR_{crop2} ($Area_{crop2}$/$Area_{total}$) + etc. In the same way the total net irrigation requirement are computed as indicated in appendix Table 4 and Table 4.12

Table 4.12 net crop water requirement (NCWR) net irrigation requirement (NIR), RWS, RIS

scheme	Area ha	NCWR	Total rain fall mm	NIR	Water delivered m3	Average Discharge m3/s	water diverted m3	RWS	RIS
ketar	453.45	461.64	433	238.32	5302206.3	0.547976	5918400	3.77	5.48
Arata	86	385.14	433	243.73	1216192.5	0.191839	2071861	7.38	9.88

A). Land productivity

I. Output per unit irrigated area (OPUIA)

By using equation 3.6 and table 4.11; the output per cropped area of Ketar and Arata chufa irrigation were found as 140,356 Birr/ha, 227,124 Birr/ha respectively for the year 2019. The main reason for the variation is, the farmers produced more of high value crops (Tomato, Onion and Papers), which accounts 40% of the irrigated land, as compared to 14% by shalot, which has a low agricultural value as compared to other crops to be grown in the study area. Areta irrigation scheme has better value than Ketar scheme (figure 4.4) due to its greater production (Birr) value as a result of the scheme covered with high-value horticultural crop than ketar scheme as output per unit irrigated area indicates the response of each cropped area on generating income. Ketar irrigation scheme has less value than Areta schemes as a result of the scheme covered with 43% of mono cropping which value fluctuate with time and has a low agricultural value as compared to other crops to be grown in the study area.

II. Output per unit of command area (OPUCA)

From equation 3.7 the output per command area 142,716 Birr/ha, 195,326 Birr/ha for kater and Areta respectively. The OPUCA value of ketar schemes is greater than the value of OPUIA due to the expansion of irrigated land increased beyond the designed or nominal command area of the schemes. The output per unit command area of Areta irrigation scheme is better than Ketar irrigation scheme as a result of more command area not under irrigation than Arata schemes (figure 4.4).

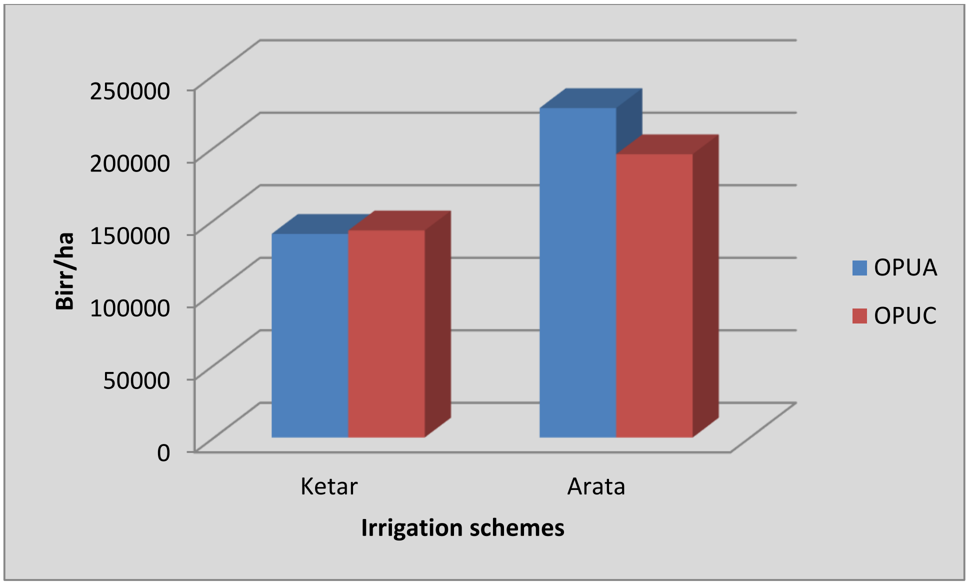

Figure 4.4 OPUIA and OPUCA of the study site

Form figure 4.4, the Arata irrigation scheme has the highest output per unit command area and the lowest was recorded in Ketar irrigation scheme. Likewise, the graph shows that the irrigation scheme has significant higher output per unit cropped area than output per command area except ketar irrigation scheme, which is an indication of cropping intensity less than one in Arata schemes except ketar scheme. This indicates all the command areas are not generating returns except ketar irrigation scheme command area generating returns.

B). Water productivity

I. Output per unit irrigation supply (OPUIS)

The total amount of water delivered to Ketar and Arata irrigation schemes were 5,918,400m^3 and 2,071,861m^3 respectively (Table 4.12) for five consecutive months. Using (Equation.3.8) Output per unit irrigation supply of Ketar and Arata irrigation schemes were 10.75 Birr/m^3 and 9.43 Birr/m^3 respectively.

II . Output per unit irrigation water consumed (OPIWC)

The outputs per unit water consumed using (Equation.3.9) for Ketar and Arata irrigation scheme was 12 Birr/m^3, 16 Birr/m^3 respectively. The reason could be because of variation in the area irrigated and crop selection; the schemes with highest value are those, which grow more of high value vegetables and more area under irrigation.

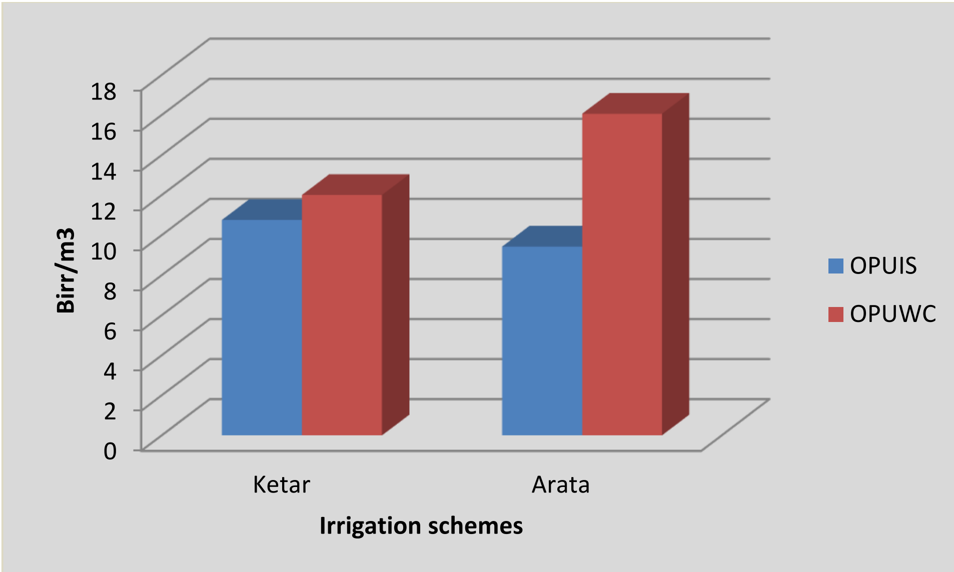

Figure 4.5 irrigation schemes water productivy

From figure 4.5, Arata irrigation scheme has higher values of output per unit water consumed than ketar irrigation schemes. This means that each unit of water applied in the field generated more yields at Arata irrigation scheme then ketar irrigation. Moreover use of inputs also affects the returns from the irrigation scheme. this result shows that the water use efficiency is better at Arata than Ketar irrigation scheme. The reason for this may be institutional set up of Arata which is stronger than at the Ketar schemes. The irrigation demand being met by the irrigation supply more at Arata and least demand met by irrigation supply at ketar irrigation scheme.

III. Relative Water Supply (RWS)

This indicator shows weather demand supply situation is mate. From the result we observe that the ratio varied between 3.77 at ketar and 7.38 at Arata irrigation scheme (Table 4.12). This indicates the crop demand meet by the irrigation supply a condition of under irrigation is not occurred at both schemes.

IV. Relative irrigation supply (RIS)

The RIS is an indicator that shows the irrigation efficiency of the scheme as a whole. Because it compares the irrigation water supplied with the irrigation water needed. The average relative irrigation supply was calculated as 5.48, 9.88 at Ketar and Arata respectively (Table 4.12). The RIS is greater than one, indicates a situation of under irrigation is not occurred, this indicates that the irrigation demand being met by the irrigation supply.

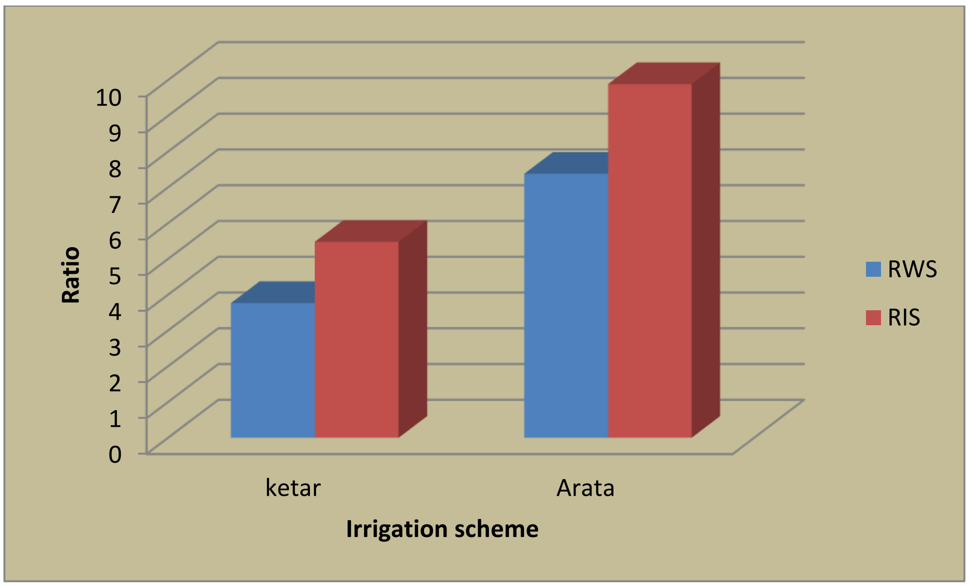

Figure 4.6 irrigation schemes Relative irrigation supply and relative water supply.

In figure 4.6, Arata irrigation scheme is better in, RWS and RIS as a result of good irrigation management. As clearly seen in the table 4.13 Areta is higher in output per cropped area and output per command. This is attributed to the high value crops and higher cropping intensity. In the case of output per irrigation supply, Ketar has the highe value implying that Ketar is better in effective utilization of water. In other ward Arata is better in land productivity and ketar is show better in water productivity.

Table 4.13.Summary of Agricultural output indicators of the four irrigation schemes

Parameters	Arata	Ketar
Irrigated cropped area (ha)	86	453.45
Command cropped area (ha)	100	446
Irrigation supplied (m3)	1216193	5302206
Water diverted (m3)	2071863	5918140
Production (Birr)	19532655	63651390
OPUIA (Birr/ha)	227124	140371
OPUCA(Birr/ha)	195327	142716
OPUIS (Birr/m3)	9.4	10.75
OPUWC (Birr/m3)	16	12
RIS (ratio)	9.9	5.5
RWS (ration)	7.38	3.77

4.4.3. Physical Indicator

I. Irrigation Ratio

Using (Equation 3.25) the irrigation ratio obtained was 1.01 at Ketar and 0.86 at Arata chufa, irrigation scheme (Table 4.14). This implies about 101% of ketar 86% of Areta command area is currently under irrigation. Lower irrigation ratio at Arate scheme might be associated with lower utilization of the given irrigable area would be existed due to different constraints; such as lack of irrigation infrastructure, lack of interest on irrigation due to less return and market problems, flooding problems and reduced productivity due to (soil nutrient depletion .Due to this reason, the cropping intensities is poor.

Similar finding reported by Zeleke (2012) as the irrigation ratio of Golgota irrigation scheme and Godino and Gohaworki subsystems of Wedecha irrigation schemes ranges from 0.67 to 0.92. This implies that 67% and 92% of the irrigable land covered by irrigation. This implies these two schemes have greater irrigation ratio.

Table 4.14. physical performance indicators

schemes	Irrigable land(ha)	Initial irrigable land(ha)	Currently irrigated land(ha)	Irrigation ratio (IR)	Sustainability of irrigation Area (SIA)
Ketar	446.04	307	453.45	1.01	1.48
Arata Cufa	100	66	86	0.86	1.30

Source: From design document and Gps survey

II. Sustainability of Irrigated Area

The sustainability of irrigated area tells about the command area under irrigation is contracting or expanding as compared to the area irrigated initially. Using (Equation 3.26) the result showed that the sustainability of the irrigated area of Ketar and Arata chufa schemes were 1.48 and 1.30 respectively (Table 4.14). This implies that the current area under irrigation was increased due to interests coming from neighboring farmers to irrigate extra land addition to designed one. This expansion of irrigable area indicates there is more sustainable of irrigation scheme.

According to Boss (1997) if the computed irrigation ratio value was less than one shows that the irrigable area becomes contracted and vise-verse. Sustainability of Areta irrigation scheme was nearly similar to Golgota irrigation scheme as reported by Zeleke (2012) was 1.33.

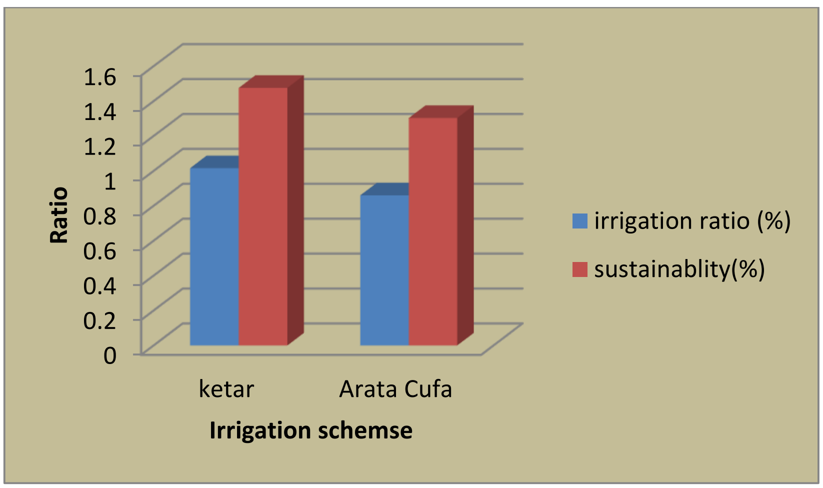

Figure 4.7. Physical performance indicators

As from figure 4.7 Irrigation ratio is higher at ketar followed then Arata irrigation scheme. Higher irrigation ratio at ketar is due to better land productivity, relative accessibility to market and farmers experience which encouraging farmers to invest on more areas. Lower irrigation ratio at Arata is due to poor irrigation infrastructures, poor market accessibility which cause lack of interest to invest more on areas.

The sustainable of irrigation area is higher at ketar then Arata irrigation scheme. On the other hand, all values of Ketar and Arata greater than one indicate expansion of irrigated area and would imply all are more sustainable irrigation schemes.

4.4.4. Organizational indicators

Organizational performance is an important indicator for the sustainability, decision making circumstances, administrative, management, and for better implementation of operation and maintenance issues and productivity of irrigation systems. Under this study; organizational structures of WUAS, Bylaws, Fee collection, Water allocation and water distributions, conflicts and conflict managements, operation and maintenance tasks of irrigation was studded.

I. Water allocation and water distributions

In all the study scheme, water allocation was rigid rotational program in water team level but for individuals it was according to spatial sequence of turns (the lands below each turnout are fed out one after the other). The amount of time allowed for each field depends on farm plot areas. It did not considered the crop types and their crop water requirements, and monthly flow amount in the canal. The WUA committees prepare the schedule by guess without any technical support from DAs or district irrigation experts.

Respondents stated that the main scheduling criteria in ranks (1st, 2nd and 3rd) were, fixed time period, water supply availability and condition of the plant in Ketar; and condition of the plant, fixed time period and water availability in Arata, respectively (Table 4. 15). These situations create to some farmers over supplied with water, while others obtained water which was far short to meet their needs as water allocation has been made by guess. Consequently beneficiaries reported the presence of power abuse and selfishness, and accuse WUAs committee

Table 4.15 Main criteria used to scheduling irrigation

Ketar irrigation scheme				**Arata chufa**		
Criteria	Frequency	Percent	Rank	Frequency	Percent	Rank
Type of plant	8	14.8	3	10	23.8	3
Fixed time periods	31	57.4	1	19	45	1
Water Availability	15	28	2	13	31	2
Total	56	100		42	100	

Data source; HHs field survey

II. Conflicts and conflict managements

Conflicts can occur between farmers at different reaches of the scheme or farmers within the same reach or block. Conflicts between head and tail reaches is mainly due to irrigation flow cut-offs at the tail ends due to excess diversions at the head or due to water shortages at the source. Conflicts between farmers within the same irrigation blocks occur mainly due to issues related to sharing of irrigation water and water theft. More frequent conflicts between farmers indicate, among others, the weaknesses of the organization in ensuring smooth operation of the scheme and water management.

Conflicts on irrigation water occur in many stages; among users in the irrigation system, between users and WUAs, and between downstream and upstream users. But at Ketar irrigation schemes conflicts between upstream users and downstream users at different system levels was main problem.

Table 4.16 Cause of conflicts over irrigation water

	Ketar			Arata chufa		
Cause of Conflict	Frequency	Percent	Rank	Frequency	Percent	Rank
water scarcity	13	24	3	16	38	2
competition due to large Number of user	23	43	1	20	48	1
water theft	18	33	2	6		3
Total	54	100		42	100	

Source: HHs field survey

The main factors for conflicts (Table 4.16) in Ketar irrigation scheme were water theft, competition due to increasing number of water users and water scarcity. However, water theft

/water abstraction/ was accounts 33% of the problems, still it is a serious issue due to lack of strict enforcement of bylaws for illegal water abstractors. This has further intensified illegal practices to obtain water and it led to conflicts among users and with WUA committees.

In Arata chufa, from the respondents 48% of them mentioned that, competition due to increasing number of water users was the main factors for their conflicts. Irrigation water users increased during peak period of the second irrigation season, crop water consumption became high and the volume of conveyed water in the canal became low. At this period the competition lifted up and it led to conflicts among users and with WUA committees.

Table 4.17: Water committee in resolving conflicts in the irrigation system

Ketar				Arata chufa		
Evaluation point	Frequency	Percent	Rank	Frequency	Percent	Rank
They take immediate action on case	15	34	3	20	47	3
They suspend cases	21	41	2	16	35	1
Have to improved	28	59	1	9	18	2
Total	54	100		42	100	

Source: HHs field survey

Table 4.17 presents that a significant number of beneficiary farmers 41% at ketar and 35%, at Arata responded that the water committee suspended cases. The rest 34% and 47% at ketar , and Arata said that the water committee take immediate action. This may due to the fact that the organizational management was weak

As from Table 4.17 the WUA committee took immediate action on the cause of conflict more at Arata result in low water theft and low competition among user. Ketar irrigation scheme WUA committee suspend case which result in more water theft and more competition among user. In general, when irrigation committee are not strong, especially at ketar irrigation scheme result in poor irrigation management which cause under irrigation of crops and reduce irrigation infrastructural efficiency.

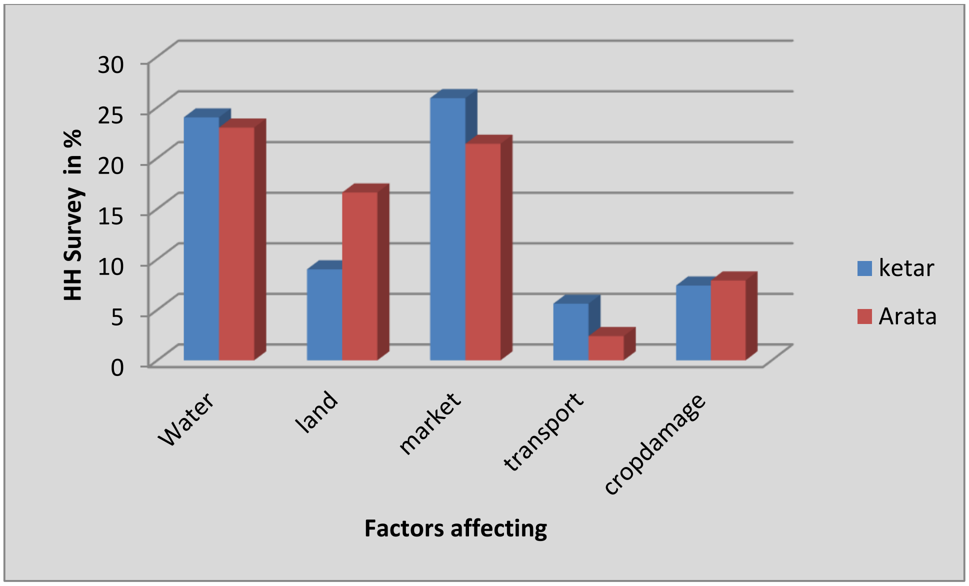

Figure 4.8 factors affecting irrigated crops in the two irrigation schemes

As from figure 4.8 water and land are main problems at ketar and Arata. This is from water theft and competition at the schemes because of high return form the two irrigation schemes. Some farmers are not interest in crop production because of some conflict due to water use especial at ketar irrigation scheme. Similarly, crop damage and land constraint are the problem at Arata irrigation schemes. This is because of lack of government support. In addition market is main problems for the two (Ketar, Arata) irrigation schemes.

4.4.5. Comparison of Performance of the Schemes

Upper and middle stream users were consuming more water than lower one, at each studded irrigation schemes and irrigation efficiency also varies along the head irrigator to tail user. But from ANOVA test, there is no significant difference in mean of conveyance efficiency, storage efficiency, application efficiency, runoff ratio and deep percolation ratio among the scheme at 5% and 10% significance level.

4.4.6. Main causes of underperformance identified

I) Major causes of under performances due to irrigation water use.

For safe functionality and durability of irrigation structures which are implemented for any developmental projects a very close and frequent overlook is mandatory. In doing this, it's better to identify and record most sensitive constraints from the minimum to the most prevailing one which further helps for giving the possible mitigation measure of the related problems which are observed.

Similarly for this research work problem identification of the four irrigation schemes were carried out through field visit and investigations made during the stay on the field. In conjunction with this the problem identification made on this part will help for the next objectives as an input to deal with it and to elaborate it further aiding with numerical values. The problems which were observed practically (figure 4.10) and those which were seen hindering its performance have been given below.

- Breakage/damage on canal and canal structure
- Clogging of Intake gate
- Very severe sedimentation of main canal and poor maintenance of structures
- Bending of the gate
- Illegal off take which cause water shortage at down user
- Method of irrigation practiced in the schemes and stream size used.
- Water logging and salinazation

II) Numbers of factors hinder the sustainability due to organizational management

- Weak water committee, that fails to effectively manage water distribution schedule.
- Poor water distribution /scheduling and failure to get sufficient water at down streams user according to design, occur mostly due to the extravagant use of head irrigators.
- Some farmers use water for their farm regardless of crop water requirement of each crop type
- Poor participation in scheme management and low water fee collected which is not used for maintenance.

III). Factors of agricultural practice which hinder the performance

- Crop variety selection and agricultural input
- Market price and transportation
- Crop damage and poor crop management
- Productivity of the land
- Low cropping intensity and lack of farmers interest to investment on irrigation.

5. CONCULUTIO AND RECOMANDETION

5.1. Conclusions

Evaluating the performance of irrigation systems is to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency. This study was conducted to evaluate the performance of irrigation schemes at Tiyo and Ziway Dugda District, Oromia Regional State of Ethiopia. The evaluation was done using internal and external performance indicators.

According to the internal indicators, the application efficiency was very low due to losses through deep percolation during irrigation events. In addition, conveyance efficiency in the unlined section of each schemes were very low due to leakage loss. The deep percolation loss was greater in Arata than Ketar irrigation schemes. The leakage loss was greater in ketar than that of Arata irrigation schemes. Because of the above observation overall efficiency of all irrigation schemes were categorized under low efficiency.

From study conducted farmers in upstream and middle stream were using excess water and siltation had affected at Ketar and Arata, night storage in downstream which caused shortage of water. In addition to the influence of up and middle stream water user competition of water user at Ketar was very series. At Ketar more conveyance loss than Arata because of short conveyance structure and strong WUA which maintain canal structure every month than other schemes.

In general, the study had shown that the schemes are not efficient technically as it has low conveyance efficiency and low application efficiency.

The agricultural output indicators were relatively better at Arata chufa Irrigation Scheme. In contrary better water supply indictors and water delivery capacity were obtained at Ketar irrigation Scheme. All schemes were sustainable according to physical indicators. However, the irrigation command area at Ketar scheme was expanding without considering water resource. This lead to scheme inadequate irrigation water supply for crop production.

From this performance evaluation study, beneficiary participation at all the four irrigation schemes in canal clearing and regular maintenance was very low. The majority of canals were covered by weeds and soils. Because the WUA's organizational function and legal enforcement of bylaws was weak.

Arata and Ketar WUAs have a detailed and written internal bylaw. However, it has not been enforced offenders who make guilty at all irrigation schemes, Except Arata chufa. As a result it should be required to increase the legal enforcement of the bylaws to protect illegal water abstractions and canal breaching, which disturb the fair water distribution systems.

Additionally, Ketar and Arata chufa irrigation schemes has better experience in collecting of annual water fees. However, there were gaps in fee collection mechanisms. And they haven't used the collected money for annual maintenance work yet. Thus, this situation hinders the motivation of farmer's attitude in participation and maintenance work

Generally, based on the evaluation carried out at each irrigation schemes would needs improvement measures to maximize the performance. Therefore, irrigation management and practice, frequent performance evaluation should be conducted to identify the critical level of the schemes.

5.2. Recommendations

Based on the result obtained from the internal and external evaluation of Ketar and Arata chufa irrigation scheme the following recommendation were suggested:

- Water delivery efficiencies at all scheme is very low. Therefore, the conveyance systems should be improved through regular canal cleaning and maintenance of broken irrigation infrastructures and canal lining where more leakage loss occurred.
- The concerned body, should give attention on guidance and support of farmers in developing and introduction of appropriate depth of irrigation, irrigation interval, in addition to improving physical infrastructure of the scheme (on canal, gate and other structures maintenance and construction) for future use.
- Preparation of extra drainage system is necessary for the schemes to avoid accumulation of excess water in the lower spots that leads to deep percolation loss.
- According to the results obtained earlier water management practices of kater was poor relative to Arata. This, can be improved by sharing experiences from Arata and other well performing scheme. Therefore farmers' development agents (DAs) and

concerned bodies of these systems better arrange visits to the sites for sharing their strong points on the other.

- Putting formal way of fee collection mechanisms and preparing of legal receipts, and finally utilize the collected money for maintenance works are relevant to create transparency.
- There is more water at Ketar, which can irrigate more command area so it need to redesign the scheme to increase command area and reduce expansion of out of command area.
- Appropriate crop selection (marketable high value crops, productivity crops and diseases resistance crops) and copping intensity with market linkage special at ketar irrigation scheme.
- Encourage community participation and strength WUC to manage irrigation schemes, as well as irrigation infrastructure.
- All irrigation organizational structures should be functional according to their responsibility.

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APPENDIX

Appendix Table 1 : Long-term (2002-2017) climatic data of the study area

Month	Minimum Temperature (0C)	Maximum Temperature (0C)	Relative humidity (%)	Wind speed (km/day)	Sunshine hour	Rainfall (mm)
January	11.3	23	51	78	8.2	13
February	12.2	23.7	54	86	8.4	26
March	14.2	24	56	86	8.3	61
April	13.9	24.8	61	95	8.1	53
May	14.8	24	58	60	8.3	52
June	13	22.7	56	43	8.4	228
July	14.3	20	73	52	6.8	286
August	12.2	19.8	84	43	6.4	287
September	12.3	20.7	80	52	7.3	97
October	12.8	22.1	86	86	8.7	81
November	13.1	22.8	58	76	9.2	18
December	14.3	22.4	54	74	9.1	9
average	13.2	22.5	64.25	69.25	8.1	100.917

Appendix Table 2: Crops characteristic data for mojar irrigation crops atfour selected schemes

		Growth Stage					
Crop	Crop parameters	intial	Dev't	Mid-Season	late season	Total	Rdz (m)
Tomato	LGP(day)	25	35	35	25	120	0.7
	Crop coefficients(kc)	0.45		1.15	0.8		
	Depletion levels(p)	0.3		0.4	0.5		
	Yield response(ky)	0.45	1.1	0.8	0.4		
potato	LGP(day)	25	35	45	15	120	0.6
	Crop coefficients(kc)	0.2		1.15	0.75		
	Depletion levels(p)	0.4		0.4	0.7		
	Yield response(ky)	0.4	0.8	1	0.7		
shallot	LGP(day)	15	25	45	25	110	
	Crop coefficients(kc)	0.7		1.05	0.75		
	Depletion levels(p)	0.37		0.35	0.29		
	Yield response(ky)	0.45	0.6	0.8	0.3	1.1	
cabbage	LGP(day)	25	30	45	20	120	0.45
	Crop coefficients(kc)	0.7		1.05	0.95		
	Depletion levels(p)	0.45		0.45	0.45		
	Yield response(ky)	0.2	0.8	0.7	0.6	0.95	
Red beet	LGP(day)	25	30	30	15	95	0.6
	Crop coefficients(kc)	0.7		1.05	0.95		
	Depletion levels(p)	0.61		0.52	0.5		
	Yield response(ky)	0.8	1.1	1	0.6	1	
onion	LGP(day)	15	25	45	15	100	0.5
	Crop coefficients(kc)	0.7		1.05	0.75		
	Depletion levels(p)	0.25	0.25	0.25	0.25		
	Yield response(ky)	0.45	1	0.3	0.3		
pepper	LGP(day)	20	35	45	20	120	
	Crop coefficients(kc)	0.35	0.75	1.05	0.9		
	Depletion levels(p)	0.25	0.25	0.3	0.25		
	Yield response(ky)	0.5	1	1.11	0.6	1.1	
Carrot	LGP(day)	20	30	30	15	100	
	Crop coefficients(kc)	0.7		1.05	0.95		
	Depletion levels(p)	0.43		0.35	0.36		
	Yield response(ky)	0.6	0.7	0.9	0.8	1	

Source: FAO I & D 24(1992) and 56(1998) papers and from house hold survey.

Table 3: Monthly average reference evapotranspiration data of the schemes(Ketar, Arata)

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate...

Country: Ethiopia | Station: Kulumsa

Altitude: 2461 m. | Latitude: 7.90 °N | Longitude: 39.14 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	13.6	26.2	53	78	8.2	19.9	3.79
February	13.8	26.6	54	86	8.4	21.4	4.26
March	12.9	27.4	56	86	8.3	22.2	4.48
April	14.1	28.5	61	95	8.1	22.0	4.58
May	15.6	28.6	58	60	8.3	21.7	4.42
June	13.4	27.0	56	43	8.4	21.3	4.13
July	14.3	23.0	73	52	6.8	19.1	3.65
August	14.1	21.1	84	43	6.4	19.0	3.48
September	13.1	21.7	80	52	7.3	20.5	3.70
October	12.4	21.0	86	86	8.7	22.0	3.72
November	12.3	22.0	58	76	9.2	21.5	3.80
December	8.8	22.3	54	76	9.2	20.8	3.53
Average	**13.2**	**24.6**	**64**	**69**	**8.1**	**20.9**	**3.96**

Appadixe Table 4 Scheme net crop water requirement and net irrigation requirement

	Ketar					Arata				
Crops	Area ha	CWR(mm /season)	IR (mm/s eason)	NCWR	NIR	Area ha	CWR(m m/seaso n)	IR (mm/se ason)	NCWR	NIR
potato	212.8	506	222.3	237.41	104.29	14.75	506	222.3	86.78	38.12
onion	95.25	389.6	236.7	81.83	49.72	26	389.6	236.7	71.56	71.56
tomato	31	432.3	245.6	29.55	16.79	15	432.3	245.6	75.4	42.83
cabbage	53.25	460.6	273.5	54.09	32.1	12	460.6	273.5	64.27	38.16
pepper	0.5	409.4	222.4	0.45	0.24	3	409.4	222.4	14.28	7.75
carrot	8.5	363.6	252.9	6.81	4.74	5	363.6	252.9	21.14	14.70
Shallot	32.2	425.9	252.9	30.24	17.95	9	425.9	252.9	44.57	26.46
gralic	9	514	286	10.20	5.67	0.75	514	286	4.483	2.49
kale	11	455	279	11.0	6.76	0.5	455	279	2.645	1.62
Total	453.5			461.64	238.317	86	0	0	385.1	243.73

	Bosha-01					Bosha-02				
Crops	Area ha	CWR(mm /season)	IR (mm/s eason)	NCWR	NIR	Area ha	CWR(m m/seaso n)	IR (mm/se ason)	NCWR	NIR
potato	8	506	222.3	58.667	25.77	6	506	222.3	58.38	25.65
onion	21	389.6	236.7	118.57	72.0	19	389.6	236.7	142.4	86.487
tomato	12	432.3	245.6	75.18	42.71	2	432.3	245.6	16.63	9.44
cabbage	16	460.6	273.5	106.81	63.42	11	460.6	273.5	97.43	57.85
pepper	14	409.4	222.4	83.0	45.12	2	409.4	222.4	15.75	8.55
carrot	6	363.6	252.9	31.61	21.99	5	363.6	252.9	34.96	24.31
Shallot	13	425.9	252.9	80.24	47.64	7	425.9	252.9	57.33	34.04
Total	69			554.16	318.71	52			422.8	246.35

Table 5. Infiltration rate computation of irrigation scheme (Ketar, Arata)

Scheme	Ketar				Arata Cufa				
Time interval (min)	Cumu lative Time (min	Infiltra tion Depth (cm)	Cumu lative Depth (cm)	Infiltrati on Rate (mm/hr)	Time interva l (min)	Cumu lative Time (min	Infiltra tion Depth (cm)	Cumula tive Depth(c m)	Infiltration Rate (mm/hr)
0	0	0	0	0	0	0	0	0	
2	2	3	3	90	5	5	2.23	2.23	28.94
2	4	2	5	59	10	15	1.8	4.03	20.6
2	6	1.3	6.3	40	15	30	1.43	5.46	16.02
5	11	2.7	9	32	25	55	1.67	7.13	9
5	16	2.7	11.7	32.8	40	95	2.31	9.44	5.93
5	21	2.3	14	27.4	55	150	1.43	10.87	5.21
5	26	2	16	24.4	70	220	1.78	12.65	4.35
5	31	1.9	17.9	22.8	85	305	1.15	13.8	4.1
10	41	3.4	21.3	20.4	105	410	1.35	15.15	3.55
10	51	3.2	24.5	19	125	535	1.19	16.34	3.01
10	61	2.7	27.2	16.2	145	680	1	17.34	2.45
20	81	4.8	32	14.5	165	845	0.86	18.2	2.07
20	101	4.1	36.1	12.2	185	1030	0.6	18.8	1.2
20	121	3.6	39.7	10.9	205	1235	0.6	19.4	1.2
30	151	4.9	44.6	9.7					
30	181	4.7	49.3	9.5					
30	211	4.7	54	9.5					

Appendix Table 6: Computation of water content bulk density and volumetric moisture content of selected schemes

	Ketar IS							**Arata** IS						
sam ple site	Wf (g)	Ws (g)	Ww (g)	Vco (g)	Bd (g/c m3)	W (%)	ϴ (%)	Wf (g)	Ws (g)	Ww (g)	Vco (g)	Bd (g/c m3)	W (%)	ϴ (%)
1	145.95	104.2	41.75	98.13	1.06	39.7	42.49	124	107.1	21.3	98.13	1.1	20.02	21.8
2	124	107.1	21.3	98.13	1.09	20	21.71	125.6	107.4	18.2	98.13	1.09	16.81	18.47
3	143.95	109.2	34.75	98.13	1.11	30.9	35.42	128.4	103.3	25.05	98.13	1.06	24.1	25.59
AVerage					1.09	30.2	33.21					1.0	20.	21.9
1	140.95	120	21	98.13	1.22	17.6	21.35	135.3	106.3	28.95	98.13	1.08	27.2	29.42

2	129.15	107.7	21.5	98.13	1.09	11	21.77	127.1	104.9	22.2	98.13	1.07	21.07	22.65
3	135.85	93.4	42.45	98.13	0.95	45.7	43.25	133.4	100.1	33.25	98.13	1.0	33.	33.8
AVerage					1.09	24.7	28.79					1.0	27.	28.6
1	144.1	103.6	40.55	98.13	1.06	39.2	41.32	142.9	107.6	35.25	98.13	1.1	32.97	35.8
2	140.7	106.4	34.3	98.13	1.06	39.2	41.32	147	111	36.08	98.13	1.13	32.48	36.72
3	139.85	111.3	28.6	98.13	1.13	25.6	29.15	156.5	124.9	31.65	98.13	1.27	25.41	32.19
Average					1.08	34.7	37.26					1.1	30.	34.9
Scheme Average					1.11	29.9	33.09					1.1	25.	28.5

Appendix Table 7. Discharge result observed using 3‟ Partial Flume at field channel

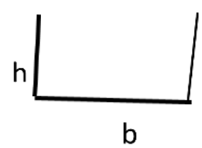
	ketar		Arata	
Sample	Fluem height (head in cm)	Respective Discharge(l/s)	Fluem height(head in cm)	Respective Discharge (l/s)
1	8	3.53	6.5	2.56
2	7	2.87	7	2.87
3	8	3.53	6	2.26
4	7.5	3.2	7	2.87
5	8	3.53	5	1.71
6	6.5	2.56	6.5	2.56
7	6	2.26	5	1.71
8	7	2.87	5	1.71
9	7	2.87	6	2.26
average	7.22	3.02	6	2.28

Appendix Table 8 Partial flume head and discharge relationship

	Through width (inch)			
	1	2	3	6
Head(cm)	Discharge (l/sec)			
2	0.14	0.281		
3	0.263	0.526	0.772	1.496
4	0.411	0.822	1.206	3.889
5	0.581	1.162	1.705	3.354
6	0.771	1.541	2.261	4.473
7	0.979	1.957	2.872	5.707
8	1.205	2.407	3.532	7.047
9	1.446	2.889	4.239	8.489
10	1.702	3.402	4.991	10. 027
11	1.973	3.943	5.786	11.656
12	2.258	4.513	6.621	13.374
13	2.557	5.731	7.496	15.177
14	2.868	6.377	8.408	17.062
15	3.191	7.048	9.358	19.027
16	3.527	7.743	10.342	21.07

17	3.875	8.46	11. 361	23.188
18	4.234	8.46	12.413	25.38

Appendix table 9: Water Flow in irrigation canal measurement and calculation using float method

	Febr			March			April		
lengths of canal reaches (L)	L1= 10m			L 2= 10			L3 = 10		
Time taken for float (sec)	T1	T2	T3	T1	T2	T3	T1	T2	T3
	10.01	9.98	9.91	10.02	10.01	9.87	9.74	9.82	10.03
Average time (T = (T1+T2+T3)/3)	9.966			9.966			9.86		
Surface flow velocity (Vs= L/T)	1.003			1.003			1.0138		
Average flow velocity (V= 0.8Vs)	0.802675585			0.802675585			0.811084826		
Dimension of the the structure	b	b	b	b	b	b	b	b	b
	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
	a	a	a	a	a	a	a	a	a
	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
	h	h	h	h	h	h	h	h	h
	0.8	0.8	0.8	0.798	0.798	0.8	0.79	0.79	0.788
Average value of (a ,b , h)	b	a	h	b	a	h	b	a	h
	1.25	1.25	0.8	1.25	1.25	0.8	1.25	1.25	0.788
Culculated wetted area A	1			0.9975			0.985		
Calculate Discharge (Q = VA)	0.803			0.800			0.798		

Appendixes Table 10: Conveyance efficiency of main canals using velocity area method

Ketar irrigation scheme						Arata Cufa irriagtion Scheme				
Observati on point (m)	Qin (l/s)	Qot (l/s)	Ec(%)	l/se	losses (%)	Qin (l/s)	Qot(l/s)	Ec(%)	l/se	Losses (%)
Intake -s1	802. 6	801	99.8	1.6	0.199	391	374	95.65	17	4.348
Intake -s2	801	778	97	23	2.871	374	372	99.47	2	0.535
Average			98	0	1.535			97.56	0	2.441
MC s1	778	704	90.4	74	9.512	372	348	93.55	24	6.452
MC s2	704	669	95.0	35	4.972	348	271	77.87	77	22.13
MC s3	669	650	97.2	19	2.84	271	218	80.44	53	19.56
MC-s4	650	630	96.9	20	3.077	218	189	86.7	29	13.3
MC-s4	630	603	95.7	27	4.286	189	164	86.77	25	13.23
MC-s5	603	489	81.0	114	18.91	164	146	89.02	18	10.98
MC-s6	489	430	87.9	59	12.07	146	141	96.58	5	3.425
MC-s7	430	328	76.2	102	23.72	0	0	0	0	0
MC s8	778	256	32.9	0	67.1	0	0	0	0	0
Average			83.7	475	16.27			89.27	210	10.73

MC- main canal and S1 ,S2, S3, S4, S5 S6 ,S7 mean sample one , two, three…eight.

Appendixes Table 11: Conveyance efficiency of secondary canal

Ketar					Arata chufa			
Observa tion point (m)	Qin (l/s)	Qot (l/s)	Ec(%)	Losses (l/sec)	Qin (l/s)	Qot (l/s)	Ec (%)	Losses (l/sec)
SC1 - 1	230.6	157.5	68.30	73.1	178	142	79.8	36
SC1 - 2	157.5	108.7	69.01	48.8	142	118	83.0	24
SC2 -1	211.7	150	70.85	91.7	138	121	87.68	17
SC2-2	150	91.8	61.2	38.2	121	97	80.16	24
SC3-1	202.8	170	83.8	72.8	119	96	80.67	23
SC3-2	170	121	71.2	29	96	78	81.25	18
Sc4-1	200.5	157.8	78.70	42.7			-	-
SC4-2	177.8	127	71.42	50.8			-	-
SC5-1	310	235	75.80	75			-	-

SC5-2	265	193	88.68	72			-	-
Average			73.9	522.1			82.0	142

Appendixes table 12 Conveyance efficiency of tertiary canal

Ketar					Arata chufa			
Observation point	Qin (l/s)	Qot (l/s)	Ec (%)	Losses (l/s)	Qin (l/s)	Qot (l/s)	Ec (%)	Losses (l/s)
TC1 - 1	17	11	64.70	6	13.7	10.8	78.8	2.9
TC1 - 2	11	8.7	79.1	2.3	10.8	8.4	77.76	2.4
TC2 -1	16	11.4	71.25	4.6	15	11.9	79.3	3.1
TC2-2	11.4	9.1	79.82	2.3	11.9	9.6	80.7	2.3
TC3-1	11.8	8.9	75.42	2.9			-	
TC3-2	8.9	6.5	73.0	3.4			-	
TC4-1	14.4	11.3	78.47	3.1			-	
TC4-2	11.3	10.2	90.26	2.7			-	
Average			76.5	3.42			79.2	10.7

Appendix Table 13 Computation of water Storage efficiency of the four studed schemes

Reach	Irrigation event	Ketar scheme Stored water at root zone (mm)	Ketar scheme Required Water (mm)	Ketar scheme Es (%)	Arata scheme Stored water at root zone (mm)	Arata scheme Required Water (mm)	Arata scheme Es (%)
Head	1	53.59	58.35	91.83	68.43	81.13	84.34
	2	67.37	72.97	92.33	95.24	107.58	88.53
	3	58.63	62.91	93.20	90.87	102.00	89.09
Average		59.86	64.74	92.46	84.85	96.91	87.55
Middle	1	39.66	42.45	93.43	79.43	92.19	86.16
	2	54.81	59.71	91.79	96.52	108.38	89.06
	3	41.06	43.22	95.00	55.61	69.31	80.24
Average		45.17	48.46	93.22	77.19	89.96	85.80
Tail	1	28.28	32.02	88.32	96.64	109.20	88.50
	2	23.36	29.40	79.45	88.82	97.73	90.89
	3	18.58	22.33	83.20	83.64	98.39	85.01
Average		23.40	27.92	83.84	89.70	101.77	88.14
Scheme Storage Efficiency				89.84			87.16

Appendix Table 14 soil texture determination of irrigation scheme

scheme	canal reach	sand %	silt%	clay %	class
ketar	Head	35	27	46	clay
	Middle	35	27	38	clayloam
	Tail	32	30	38	clayloam
average		34	28	40.667	clay loam
Arata cufa	Head	30	32	38	clay olam
	Middle	26	36	38	clay loam
	Tail	25	37	38	clay olam
average		27	35	38	clay loam
Bosha-01	Head	32	30	38	clay
	Middle	31	26	43	clayloam
	Tail	35	27	38	clayloam
average		32.67	27.667	39.667	clayloam
Bosha-02	Head	25	37	38	clayloam
	Middle	34	24	42	clay
	Tail	29	35	36	clay loam
average		29.33	32	38.667	clayloam

Appendix Figure 1: Field measurement practes conducted at Arata chufa

Partial flume outlet side soil sample weight

Inflitrometer partial flume inlet

Appendix Figure 2: Condition of irrigation structures and its Mismanagement

Irrigation canal condition **damaged drop structure**

Damaged off take gate **using stone to divert water to intake**

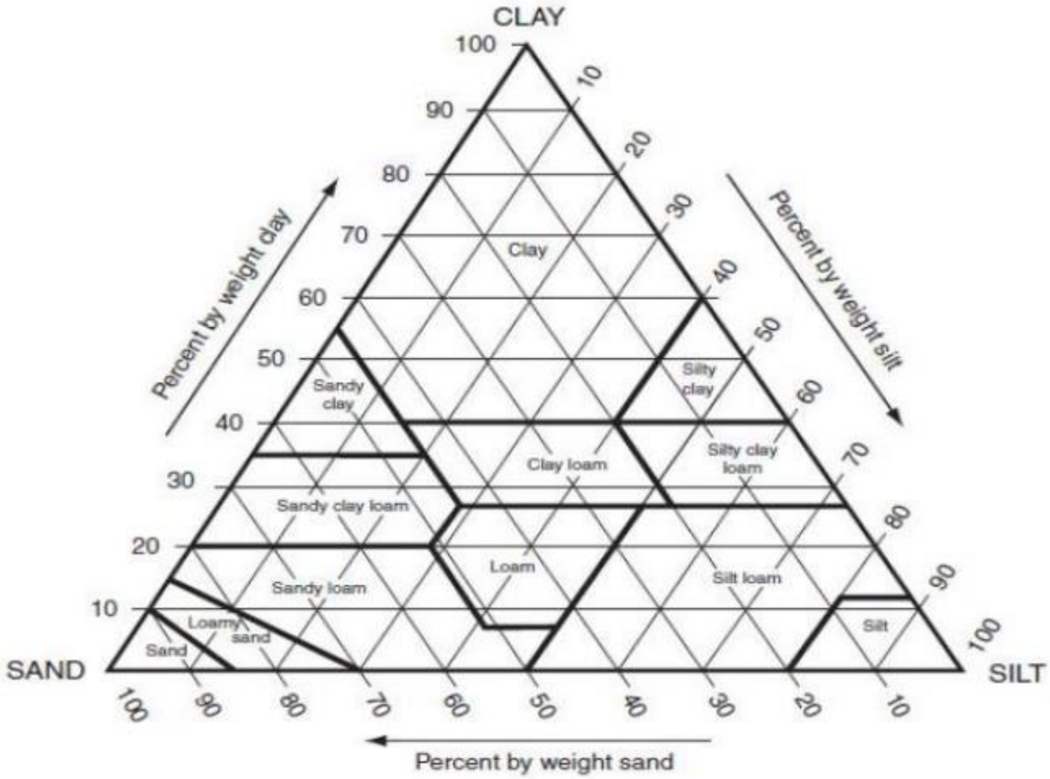
Appendix Figure 3: Furrow types practiced in the area and water application in furrows.

Appendix Figure 4: Mismanagement of irrigation water and it cause

High runoff loss at tail of furrow irrigation salinity start to developed

Illegal off take by canal cutting High conflict between upper and down user

Appendix Figure 5 Soil Textural Class Triangle


CLAY
SAND
SILT
Percent by weight clay
Percent by weight silt
Percent by weight sand
100
90
80
70
60
50
40
30
20
10
Clay
Sandy clay
Silty clay
Clay loam
Silty clay loam
Sandy clay loam
Loam
Sandy loam
Silt loam
Loamy sand
Sand
Silt