PERFORMANCE EVALUATION OF IRRIGATION SCHEME - THE CASE OF RATTE LARGE SCALE IRRIGATION SCHEME, DASENCH WOREDA, SOUTH OMO, ETHIOPIA.

MSc THESIS

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HAWASSA UNIVERSITY HAWASSA, ETHIOPIA

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Dedication

I dedicate this thesis manuscript to my father Haile Bordie Lola and my mother Elfinsh Waqejira for nursing me with affection and love and for their dedicated partnership in the success of my life.

Statement of author

I, the researcher, Bubu Haile Bordie declare that this thesis is my original work, and it is not and will not be presented to any other university for pursuing a similar degree award. Moreover, all the sources of materials used for the thesis are duly acknowledged.

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Acronyms and Abbreviation

A	Area of cross-section
CWR	Crop water requirement
E_a	Application efficiencies
E_c	Conveyance efficiencies
E_s	Storage efficiencies
E_o	Overall, all efficiencies
ETc	Crop evapotranspiration
ETo	Reference- evapotranspiration
ETp	Potential crop evapotranspiration
FAO	Food and agriculture organization
FWWDSE	Federal water work design supervision enterprise
GPS	Geographic position system
GIS	Geographic information system
IWR	Irrigation water requirement
IWMI	Integrated water management institute
LSIS	Large scale irrigation scheme
MOAR	Ministry of water resource
Qd	Actual delivered discharge
Qi	Inflow discharge
Qo	Outflow discharge
Qr	Actual requirement discharge
SNNPRS	South nation nationality people regional state
TAW	Total available water

Contents

Abstract

Ratte large-scale irrigation scheme is located in the in Dasench woreda, South Nation Nationality people regional state, Ethiopia, and had a service of five years. However, the performance of the irrigation scheme has not been evaluated yet. In the present study, the performance of the scheme was evaluated by estimating water delivery performance indicators, water conveyance efficiency, water conveyance losses, and satisfaction of irrigation users. The water delivery performance were evaluated by monitoring discharge at nine selected offtakes; three each at the head, middle and tail end of the scheme command area during the crop season from April to June 2022. The water conveyance efficiency of the main and secondary canals and thus the water losses in water conveyance were estimated by measuring irrigation water flow at different locations along the canals. The satisfaction of the irrigation water users from the irrigation service received was evaluated manually at the head, middle and tail end of the irrigation scheme, and for the entire irrigation scheme. Irrigation water flow in the main and secondary canals, as well as at nine tertiaries off takes was measured using float velocity method and 3-inch Parshall flume. The data were analyzed using CROPWAT 8.0, ARC GIS software, and Microsoft Excel. The analysis of internal performance indicators showed that the conveyance, application, storage, and overall irrigation efficiencies, and distribution uniformity were 57.3 %, 63.6 %, 88.17 %, 36.2 %, and 88.6% respectively while the deep percolation ratio is 35.7 %. respectively. The loss in conveyance was unavoidable unless the canal was lined or could be minimized with better canal management activities. Approximately 35.6% of beneficiaries express satisfaction with the irrigation services provided. It was generally found that the irrigation service provided to the user was insufficient, and the program's intended beneficiaries did not receive the benefits. Rearranging WAUs, improving user capacity, and optimizing water delivery scheduling. In summary, in order to optimize irrigation and water management, it is crucial to give careful consideration to converting unlined canals to lined ones and to exchanging water use management best practices from various irrigation projects that enhance the scheme's performance.

*K**eywords**: - Ratte large-scale irrigation scheme, Water delivery performance, conveyance efficiency, users' satisfaction*

Introduction:

1.1. Background

Water is essential for every form of life, for all aspects of socio-economic development, and for the maintenance of healthy ecosystems. While there are sufficient freshwater resources at the global level to enable continued agricultural and industrial development, the long-term sustainable use of water resources is of growing concern. This is particularly the case when considering the intrinsic disparity in water quality and availability across regions. (FAO 2017: Water for Sustainable Food Agriculture)

As population growth and rising incomes continue to drive demand for water, increasing competition between water, energy, agriculture, fisheries, livestock, forestry, mining, transport, and other sectors may have unpredictable impacts on livelihoods and the environment. Large-scale water infrastructure projects, for instance, provide electricity through hydropower and water storage for irrigation, flood management, and urban uses, but can have large adverse impacts on the environment, downstream agro-ecological systems, and local communities and their livelihoods. (FAO 2017: Water for Sustainable Food Agriculture)

Rain-fed Agriculture has failed to produce enough food to meet the increasing demand for food among the rapidly growing population. To meet this demand, significant investment in irrigation with improved performance of irrigation schemes is important. It was identified that globally, 60% of the diverted fresh water for agriculture does not contribute directly to food production (Dejen, 2015). It depicts that only about 40% of global fresh water abstracted for irrigation is being effectively used for consumptive use in agriculture. This amount of water is lost because of poor water management, inefficient irrigation systems with leaky conveyance and distribution, and poor on-farm water management practices, etc. Therefore, the performance of irrigation schemes should be evaluated to minimize water losses, improve irrigation water use efficiency, and improve scheme performance accordingly. Ethiopia has a large amount of cultivable land (30 to 70 Mha), but only about a third of it is currently cultivated (approximately 15 Mha), with current irrigation schemes covering approximately 640,000 ha across the country. However, the study estimates that Ethiopia's total irrigable land potential is 5.3 Mha if existing technologies are used, including 1.6 Mha through RWH and groundwater. This implies that there are opportunities to significantly increase the amount of irrigated land (Awulachew 2010)

Performance evaluation in irrigation and drainage is the systematic observation and interpretation of the management of irrigation schemes with the objective of ensuring that the input of resources, operational schedules, and required actions proceed as planned. Performance can be assessed for a variety of reasons: to improve system operation, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess the impact of interventions, to diagnose constraints, to better understand determinants of performance, and to compare the performance of a system with the same system over time or with other systems (Alemayehu, 2016).

Irrigated agriculture is of major importance in many countries all over the world. It is important in terms of food security, public development, and settlement for rural people. As world population growths significantly, the need for more effective and efficient use of land and water resources is increasing (FAO, 2017). Despite their potential for agricultural growth, there is a remarkable decrease in the performance of several irrigation projects, especially large-scale systems, which usually perform far below their potential capacity (Alcon et al., 2017; Bos et al., 2005; Dejen, 2015; Murray-Rust and Snellen, 1993). This is mainly due to the poor resources management, absence of the planned benefits, and the negative health and environmental impacts (Biswas, 1990). This situation has resulted in an increase of interventions directed to improve irrigation projects performance. Many studies were conducted to investigate the performance assessment and diagnosis in irrigation systems from worldwide regions (Asia, Africa, Europe, and South America).

However, especially in the South Omo Zone performance evaluation of irrigation schemes is rarely conducted. So, this study assesses the performance of the Ratte large-scale irrigation scheme in the southern nation, nationality, and people regional state (SNNPRS) of Ethiopia South Omo Zone Dasenech woreda using internal indicators. The study will contribute to increments in the productivity of the study area by providing basic information on irrigable land, availability and quality of water, and sound land management methods for irrigation projects. Addition of, knowledge and experience will be gained from this study could be transferred to other similar areas of the country to assist the existing irrigation project

1.2. **Statement of Problem**

Developing nations have poured enormous sums of money into building irrigation infrastructure and providing farmers with facilities. Many countries have been able to achieve food self-sufficiency and boost food production through this investment and advancements in crop production technologies. The performance of the entire irrigation scheme is not according to the intended objectives if the scheme is not managed and operated properly. Many irrigation schemes, particularly in least developed and emerging countries, are characterized by a low level of overall performance (Dejen, 2015;2016).

The public irrigation schemes in these countries have generally performed far below potential in terms of both technical and economic aspects. Thus, it is essential to assess the irrigation schemes' performance in order to make sure they are operating smoothly, spot any gaps, and implement corrective action.

To address the need for increased productivity of irrigated lands under pressure on water resources, improving the performance of irrigation schemes through various interventions is thought to be crucial. Users of irrigation systems may or may not be happy with the irrigation water provided by the programme. In certain situations, the degree of dissatisfaction may arise from a willingness to apply more water than is actually required for crops and a lack of awareness of the negative effects of excessive water use in crop production. On the other hand, the degree of discontent could result from the irrigation water supply's dependability in meeting users' timely demands.

Irrigation systems with poor management have the potential to degrade and waste valuable land and water resources. Rate large-scale irrigation scheme is now irrigated about 250 ha whereas its proposed design was to irrigate about 10000 ha that. There are some shortcomings to become the irrigation scheme below its potential such as poor operational and maintenance of the irrigation system and improper irrigation practices leading to poor water management which reduces the potential of the irrigation scheme. However, users of some irrigation schemes might be content with the quality of service provided by the scheme. As a result, it's important to assess user satisfaction and raise awareness of the negative effects of using too much water. Ratte large scale irrigation scheme costs huge amount of money for construction of the scheme and creation of irrigation facilities. This irrigation scheme enables the irrigation users to enhance crop production and improve their livelihood. Still unassessed, however, are the irrigation scheme's effectiveness and the degree of user satisfaction with the water supplied for irrigation. Consequently, the purpose of this study is to appraise the irrigation scheme's water delivery efficiency and gauge the users' contentment with the irrigation water that the scheme provides.

1.3. General objective

The general objective of the study is to evaluate the delivery performance of Ratte large-scale irrigation schemes using internal indicators and level of users’ satisfaction with irrigation service

1.3.1. Specific objective

- To evaluate water delivery performance of Ratte large-scale irrigation scheme.
- To determine the satisfaction of users from the irrigation service received.
- To identify the gaps and recommend remedial measures that improves the performance of the scheme

1.4. Research question

- Is the performance of water delivery from the irrigation scheme good?
- Does the irrigation system convey water efficiently?
- Are the irrigation users satisfied with the irrigation service?
- Are there alternative options to improve the performance of the irrigation scheme?

1.5. Significance of the Study

The results of this study will be very beneficial to irrigation users as well as scheme managers. Assessing its performance entails determining how successful the irrigation plan is. As a result, this will help us determine whether or not maintenance and other options for improvement are necessary. The strengths and weaknesses of the system will be identified by various stakeholders, including farmers, scheme managers, and policymakers. Based on these findings, potential solutions for enhancing system performance and achieving maximum efficiency will be considered. Additionally, this study will offer baseline data for future research of a similar nature for the creation of new irrigation plans in other command areas.

2. Literature review

2.1. Global Water Resource

Water resources are sources of water that are useful or potentially useful to humans. Uses of water include agricultural, industrial, household, recreational, and environmental activities. Virtually all of these human uses require fresh water 97%/ .water on the Earth is salt water, leaving only 3% as freshwater of which slightly over two-thirds is frozen in glaciers and polar ice caps. The remaining unfrozen freshwater is mainly found as groundwater, with only a small fraction present above ground or in the air (Mars 2016).

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Fresh water is a renewable resource, yet the world's supply of clean, fresh water is steadily decreasing. Water demand already exceeds supply in many parts of the world and as the world population continues to rise, so too does the water demand. Awareness of the global importance of preserving water for ecosystem services has only recently emerged as, during the 21st century, more than half the world's wetlands have been lost along with their valuable environmental services. Biodiversity-rich freshwater ecosystems are currently declining faster than marine or land ecosystems (Mars 2016).

2.2. Irrigation Concept

Irrigation can be defined as an artificial application of water to soil for the purpose of supplying the moisture essential in the plant root-zone to prevent stress that may cause reduced yield and/or poor quality of harvest of crops (Reddy, 2010). This is an intentional action made by human to apply water for growing crops, especially during dry seasons where there is a shortage of rainfall. Water applications to crop fields are of various types. The most commonly used and most ancient type is surface irrigation methods (FAO, 2002) through the usage of gravity forces. This was used especially across river sides and it doesn't depend on mechanized equipment's. Nowadays, modernized irrigation systems are mostly used which works based on the pressurized energy system (FAO, 2001). The sprinkler and drip irrigation systems are of this type of water application systems. Water is mankind's most vital and versatile natural resource (Nata et al., 2008) and has always played an essential role in Ethiopian society as it is an input to almost all production systems (MoWR, 2006). Water is also considered as an essential resource for irrigation.

2.3. Historical development of irrigation globally

Global crop productivity has increased due to the spread of irrigated agriculture, but freshwater resources are under severe stress as a result. One of the main goals of sustainable agriculture is to guarantee that increases in irrigated production only take place in areas with relatively abundant water. Understanding the evolution of irrigated land is crucial for tracking the movement towards water sustainability.

In the world, irrigation may be considered to date back to the prehistoric times in Mesopotamia and Egypt where they were used to water crops. Irrigation is an ancient agricultural practice that was vastly used by many countries of those early civilized such as Egypt, China, India, and Iraq (Grove, 1989). Over 5000 years ago, runoff irrigation was practiced in Yava, Palestine. At the same time, so-called hydraulic societies developed in large river valleys, such as the Yangtse in China, the Indus in India, the Euphrates in Iraq, and the Nile in Egypt. Laws and by-laws regulated the distribution of irrigation water, which dominated the life cycle of farmers and citizens alike. Some 1500 years ago, the Marib dam in Yemen raised the water level of a non-perennial river to divert floods for irrigation purposes (FOA, 1999). From the above, one can understand irrigation is an age-old art, perhaps as old as civilization. Nevertheless, the increasing need for crop production due to the growing population in the world is necessitating a rapid expansion of irrigated agriculture throughout the world, especially small-scale irrigation. Since then, there have been numerous innovations that have helped improve the ease and efficiency of water application to crops.

Irrigation has turned many of the earth's driest and most fertile lands into important crop-producing regions. For example, Egypt grows virtually no food without water drawn from the Nile or underground aquifers. California's Central Valley and the Aral Sea basin—the fruit and vegetable baskets of the United States and the former Soviet Union—produced little without irrigation. The world's major grain-producing areas of northern China, northwest India, and the U.S. Great Plains would drop by one-third to one-half without irrigation to supplement rainfall. Irrigation fills a key role in feeding an expanding world population and seems destined to play an even greater role in the future. (FAO, 2021).

As practiced in many places, however, irrigation is still based largely on traditional methods that fail to measure and optimize the supply of water to satisfy plant water demands. Unmeasured irrigation tends to waste water, nutrients, and energy and may cause soil degradation by waterlogging erosion, and Salination. The vital task of assuring adequate global food production must include a concerted effort to modernize irrigation systems and improve water management. These improved techniques will help achieve sustainable and efficient production while protecting the environment. New systems must be based on sound principles and designs to optimize irrigation with essential inputs and operations while guaranteeing the sustainability of irrigated agriculture. Water and soil must be recognized as vital, precious, and vulnerable resources and managed accordingly. (FAO, 2021).

2.4. Irrigation development in Ethiopia

According to Awulachew et al., (2010), there is no documented history of water management for agriculture. In Ethiopia irrigation can be dated back to the millennium-old water storage structures for non-agricultural was used around Axum in Tigray showing the oldest usage of water in a controlled manner. However, there is no well-documented resource material on water use for irrigation in Ethiopia. Modern irrigation development in Ethiopia is not having centuries

Modern irrigation was started at the beginning of the 1960s by private investors and was concentrated in the middle of Awash Valley (Zerihun and Ketema, 2006). In Ethiopia, irrigation has long been in use; however, irrigated agriculture is far from satisfactory despite substantial investment, public interest, and strategic support through government policy. Irrigated agriculture comprises only 3% of the total national food production (Tilahun & Paulos 2004). Irrigation is the supply of water to crops by artificial means. It is designed to permit the desired plant growth in arid regions and to offset drought in semiarid regions or sub-humid regions. Even in areas where average seasonal precipitation may seem ample, rains are frequently unevenly distributed, or soils have low water-holding capacities so traditional rain-fed agriculture is a high-risk enterprise. Irrigation provides a means for stable food production. In some areas, irrigation prolongs the effective growing season. With the security provided by irrigation, additional inputs like higher producing varieties, additional fertilizer, better pest control, and improved tillage, become economically feasible. Irrigation reduces the risk of these expensive inputs being wasted by drought. On a global scale, Irrigation has a profound impact on freshwater supplies, world food production, and the aesthetics and value of landscapes. One-third of the world's food comes from the 21% of the world's cultivated area that is irrigated In the U.S., irrigated agriculture accounted for about half of the total value of crop sales on 28% of harvested cropland in 2012 (USDA, 2019**;** FAO, 2021.)

2.5. Type of irrigation scheme

The Ethiopian Ministry of Water Resources classifies irrigation schemes based on the size of the command area into small-scale (less than 200 ha), medium-scale (between 200-3,000 ha), and large-scale (>3,000ha) irrigation schemes. (MoWR) (2002), Accordingly, 46% of the proposed irrigation developments in Ethiopia are small-scale irrigation schemes. Similarly, based on the history of the establishment, the management system, and the nature of the structures (Wambua et al., 2011). Modern schemes are those equipped with permanent irrigation infrastructures such as water diversion (headwork), flow control structures, and conveyance and distribution systems (Dejen et al., 2012). Traditional schemes do not have permanent structures for water acquisition and flow control and are made using local knowledge with local materials; including stones, soils, wooden logs, sandbags, etc. These are constructed by the efforts and initiatives of the farmers and are reconstructed every year. (Zeleke Agide 1 & Amare Haileslasie,2016.)

2.5.1. Large-scale irrigation scheme in Ethiopia

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

2.6. Performance evaluation of large-scale irrigation schemes

Irrigated agriculture is of major importance in many countries all over the world. It is important in terms of food security, public development, and settlement for rural people. As world population growths significantly, the need for more effective and efficient use of land and water resources is increasing (FAO, 2017). Despite their potential for agricultural growth, there is a remarkable decrease in the performance of several irrigation projects, especially large-scale systems, which usually perform far below their potential capacity (Alcon et al., 2017; Bos et al., 2005; Dejen, 2015;)

The purpose of performance assessment is to achieve efficient and effective use of resources by providing relevant feedback to the management at all levels Moreover, it helps with obtaining useful information in order that corrective actions may be taken to maximize the benefits of the irrigation project. The performance evaluation also could help with verifying the relevant project lessons learned and developing benchmarks to improve planning, implementation, and management of similar projects. Performance evaluation can be carried out at the sector level, scheme level, main system level, and on-farm level (Bos et al., 2005). At the sector level when assessing how irrigation and drainage are performing in comparison with the objectives set for the sector, and in comparison, with other uses of water. At the scheme level, performance evaluation is carried out to assess how individual schemes are performing against their own explicitly or implicitly stated objectives (Awulachew & Ayana, 2011).

At the main system level where the performance of the water delivery service is assessed; on this level performance assessment is focused on water delivery, which will depend on the management, operation, and maintenance processes and procedures of the main system service provider. At the on-farm level where the performance of the on-farm water delivery, water use, and water application is assessed. The formal determination of the contribution of an individual component related to the outcome of a project within a particular setting to measure the achievements above or below the standard is termed performance evaluation. Performance evaluation provides different stakeholders (system managers, farmers, and policymakers) with a better understanding of how a system operates (Bouml & Demir 2009

2.7. Types of Performance Indicators

2.7.1. Internal performance indicators

Many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated; and cropping patterns. A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users.Targets are set relative to objectives of system management, and performance measures tell how well the system is performing relative to these targets When the performance is not adequate, either the process must be changed to reach the target, or the target itself must be changed. These “internal” indicators aid irrigation system managers to answer the question “Am I doing things, right?” (Murray et al., 1993).

The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field (Feyen J, Zerihun D.1999). The common efficiency terms used for on-farm irrigation system evaluation (internal process indicators) include conveyance efficiency, application efficiency, Storage efficiency Distribution uniformity, and Overall efficiency, are being applied (Jureims et al., 2001). The principal terms and their uses are described as follows. Irrigation efficiency is defined as the ratio of the amount of water needed for a proposed purpose divided by the total amount of water diverted to the necessary place (Mati, 2011).

2.7.1.1. Water conveyance efficiency (E_c)

Water conveyance efficiency is the ratio, in percent, of the amount of water delivered by a canal or pipeline to the amount of water delivered to the conveyance system. Water conveyance efficiency is used to measure the efficiency of the water conveyance system associated with the canal network, watercourses, and field channels; it is also applicable where the water is conveyed in channels from the well to the individual fields. It is one of the several closely related and commonly used output measures of performance that focus on the physical efficiency of the water conveyance by the irrigation system (Bos,1997). According the Ramulu, (1998) conveyance efficiency (Ec) mainly depends on the length of the canals, the soil type or permeability of the canal banks, and the condition of the canals. Some indicative values of the conveyance efficiency (Ec), considering the length of the canals and the construction materials in which the canals are constructed have different values. For instance, for lined canals for all lengths of canals, the recommended E_c is 95% (Mati, 2011 FAO, 2002.)

2.7.1.2. Water application efficiency (E_a).

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. The objective is to apply the water and store in the crop root zone to meet the crop water requirement. Water application efficiency (Ea) is a measure of the fraction of the total volume of water delivered to the farm or field to that which is stored in the root zone to meet the crop evapo-transpiration needs. Water losses during surface (furrow) irrigation include runoff, evaporation from water in the furrow channels, evaporation from the soil surface, and percolation below the root zone.

According to (FAO, 2003) reported that the attainable application efficiency US according ranges from 55% - 70%. The efficiency values presented strong functions of soil type, slope, crop growth stage, system / water delivery capacity, and many other management factors and field and irrigation method characteristics. Thus, for the same irrigation method, these values can vary substantially from one field or location to another. Proper irrigation management can increase the increase the application efficiency, and poor irrigation management can result in inefficient use of water and reduce application efficiency. Over irrigation may result in leaching chemicals below the crop root zone, cause yield reduction, and result in wasting water resources. Improper timing and inadequate irrigation applications that do not meet the crop water requirement may impose stress to the crop and reduce grain yield and yield quality.

2.7.1.3. Water storage efficiency (E_s)

According to (FAO, 2003) noted that water stored in the root zone is not 100% effective. Evaporation losses may remain fairly high due to the movement of soil water by capillary action towards the soil surface. Water is lost from the root zone by deep percolation where groundwater is deep.Deep percolations can persist after attaining field capacity. Small irrigation may lead to high water application efficiencies, yet the irrigation practice may be poor. The concept of water storage efficiency is useful in evaluating this problem. This concept relates to how completely the water needed before irrigation has been stored in the root zone during irrigation.

According to (Wang, Zerihun, & Feyen, 1996), water storage efficiency (Es) is defined as the ratio of the volume of water stored in the root zone to the volume of water required to fill the root zone to near field capacity. The maximum amount of water that should be applied to achieve high storage efficiency for a given irrigation event is the difference between the field capacity and average water content in the soil root zone before the irrigation events.

According to (Lesley, 2002) showed that the storage efficiency could be in the range of 50% -70%. High storage efficiency means that the irrigation brings the soil root zone to field capacity, but does not lead to deep percolation. In furrow irrigation, the usual practice is to irrigate every other furrow to provide more storage space within the root zone for potential rainfall. In such cases, the use of storage efficiency may be meaningless because the goal with application efficiency is not to maximize root zone water storage. Storage efficiency depends on the soil type, average root zone depth, and used for irrigation water management.

2.7.1.4. Distribution efficiency (Ed)

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

2.71.5. Overall irrigation system efficiency (E_o)

The overall irrigation efficiency is the total process of irrigation from the source of the water to the point where the water becomes available in the root zone of the plant. Irrigation efficiencies are evaluated at the scheme or farm level to identify the losses that occur in the irrigation system starting at the water abstraction point, through the conveyance system down to water application in the field (Jensen, 1983.)

a) Irrigation ratio

Sener *et al.* (2007) developed a relation between currently irrigated areas to the command (nominal) area to be irrigated; to quantify the level of utilization of the potential irrigable area for irrigated agriculture for a particular production time period. Lower utilization of the given irrigable area would be existed due to different constraints; i.e., lack of irrigation infrastructure, shortage of irrigation water, lack of interest in irrigation due to less return and market problems, and reduced productivity due to (soil nutrient depletion, lack of improved technologies, lack of inputs and waterlogging) etc. Furthermore, cropping intensity is an illustrative for land utilization capacities. The cropping intensities from 100 to 200% are considered good, while a lower ratio indicates poor intensities (Burton *et al.,* 2000).

b) Sustainability of irrigated area

According to Bos (1997), the sustainability of irrigated areas is the ratio of currently irrigable areas to initially irrigated areas. This important indicator is 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 1, it shows the irrigable area is expanded from the designed irrigable area, including nearby farm areas. The contraction of irrigable land may appear due to different reasons, i.e., water shortage, water logging, flooding problems, etc. On the other hand, expansion might occur due to interests coming from neighboring farmers to irrigate extra land in addition to the designed one. This expansion of irrigable areas indicates there is more sustainability of irrigation.

2.8. Crop water and irrigation water requirement

Crop water requirement is defined as the depth of water required to meet the water lost through evapotranspiration (ETC) of a disease-free crop, growing in a large field under non-restricted soil conditions. Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between them. Evapotranspiration is the combination of the two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration. When the crop is small, water is predominantly lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process (FAO, 1998).

The first procedure is a determination of reference crop evapotranspiration (ETO). It is defined as the rate of evapotranspiration from an extensive surface of 8 to 15cm tall green grass cover of uniform height, actively growing, completely shading the ground, and no shortage of water. This tells us the effect of climate on crop water requirements. Blaney Craddile method, modified Penman-Monteith method, radiation method, and pan evapotranspiration method are some of the ETO estimation methods. The modified Penman Montieth method was used to estimate ETO using CROPWAT software for the present study. This is because; the method has been found more accurate than the other methods (FAO, 1998). For the computation of ETO using CROPWAT software, the FAO-modified Penman-Monteith method requires radiation, air temperature, air humidity, and wind speed climatic data. Irrigation is required when rainfall is insufficient to compensate for the water lost by evapotranspiration. The primary objective of irrigation is to apply water at the right time and in the right amount.

If irrigation is the sole source of water supply for the plant, the irrigation requirement will always be greater than the crop water requirement to allow for the inefficiencies in the irrigation system. If the crop receives some of its water from other sources (rainfall, water stored in the ground, underground seepage, etc.), then the irrigation requirement can be considerably less than the crop water requirement.

The irrigation requirement (IR) is one of the principal parameters for the planning, design, and operation of irrigation and water resources systems (FAO, 1998) Not all dependable rainfall is effective and some may be lost through surface runoff, deep percolation, or evaporation (FAO, 1978). Only part of the rainfall can be effectively used by the crop, depending on its root zone depth and the soil storage capacity. In its simplest sense, effective rainfall means useful or utilizable rainfall FAO (1978). Rainfall is not necessarily useful or desirable at the time, rate, or amount in which it is received. Some of it may be unavoidably wasted while some may even be destructive. Different methods exist to estimate the effective rainfall; one of the most commonly used methods is the USDA Soil Conservation Service Method (FAO, 1986).

2.8.1. Estimation of crop water and irrigation water requirements:

The CROPWAT model requires ETo, effective rainfall, and crop data for estimating CWR and IR. Reference evapotranspiration (ETo): the FAO Penman-Monteith equation has been adopted as the globally best-performing method of estimating ETo based on the input's geographical coordinates (Latitude, longitude, and elevation) of the nearby metrological station, and monthly climatic data (minimum and maximum temperature, relative humidity, sunshine duration, and wind speed). ET0 for each month was calculated for ten days (Supeet., 2015)

2.8.2. Effective rainfall.

There are about four available options for calculating effective rainfall. These are: Fixed percentage, dependable rainfall (FAO/AGLW formula), empirical formula, and USDA soil conservation service methods. Effective rainfall is calculated based on rainfall inputs data collected from the nearby station gage (Supe et al., 2015).

CROPWAT Model

Low agricultural water productivity in irrigated agriculture and very low food security is challenging due to high population explosion and water exploitation in agriculture in both developed and developing countries in the world. CROPWAT model is decision support system developed by FAO and it is used as practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements, irrigation scheduling, and also allows helps in planning and decision making in the areas were water resource availability is varying and scarce. Therefore, understanding crop water requirements (CWR) is essential for better irrigation practices, scheduling and efficient use of irrigated water since climatic variability and water scarcity is in every corner in the globe (Abdul H. Halimi and Ashebir H. Tefera 2019).

According the Thorsten; (2006) CropWAT model is described as decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. CropWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements using the inputs of climatic crop and soil data. Crop data consisting of the planting date, growth stage in the day's crop coefficient (Kc) values, root depth, depletion fraction, and the cropped area in percent (%) of the total area. The crop coefficient integrates the effects characteristics that distinguish a typical field crop from the grass reference, which has a constant appearance and complete ground cover. Consequently, different crops will have different crop coefficients. Growth stage as the crop develops, the ground cover, crop height, and leaf area change. Due to the difference in evapotranspiration during the various growth stages, the Kc for a given crop will vary over the growing period. (Allen et al. 1998)

Irrigation scheduling

The CROPWAT model estimates the irrigation scheduling with the soil data inputs. The soil data include TAM, maximum rooting depth, and initial soil moisture depletion. The irrigation scheduling shows the status of the soil moisture whenever new water enters into the soil, either from rainfall or irrigation water (Supe et al., 2015)

Organizational performance indicators

Organizational performance indicator is an important factor of the sustainability and productivity of irrigation systems (Blank and Hammord 2002). 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 in equitable water distribution, corruption, inefficiency, drainage, and poor operation and maintenance. According to Blank and Hammord (2002) few among the institutional arrangements which facilitate collective action in irrigation systems, and include the following; -

- Users' organization and their by-laws, and enforcement characteristics
- Stakeholders and their relationships in irrigation management (concerned government agencies, farmer's organizations, and users, Effective water control in irrigation management is a function several factors including physical, technical, socioeconomic, organizational, political, cultural, and complex institutional factors (Eticha 2011.)

2.8. ***The roles of water users' associations;***

Attention is nowadays being focused on how to achieve this commitment, and to what extent WUAs can be assisted to form and manage their own affairs (FAO 1996). Many conflicts occur due to the problem of water theft or unauthorized canal breaching in the scheme. There is a conflict resolution mechanism and most WUAs develop their by-laws which is a system of rules for controlling the conflict within the scheme. The WUAs committees have long existed to manage LSI schemes. The associations handle construction, allocation, operation and maintenance functions with government technical and material support (MoWR, 2002). The inefficient and underutilization of the available capacity of the schemes in Ethiopia arise from giving more emphasis to technical aspects and less emphasis to the managerial and institutional issues. It can be evaluated quantitatively and qualitatively in the form of (MoA 2010);

- Organizational structure and functions of WUAs
- Beneficiary participation in operation and maintenance
- Water allocation and water distributions
- Conflict resolution mechanisms

2.9. Users' satisfaction with Irrigation Service

Satisfaction captures the customers' response to a particular service - how the customer feels about the service received. There are different factors that can influence farmer satisfaction with irrigation schemes. Some of the factors are technical, agricultural, social, or economic while some are institutional (Hill et al. 2008).

There is no statistical model which is the right one for a specific research problem, but there is the best, which can be described as offering more ways to infer specific characteristics (Corty, 2007). Different models are used for evaluating the probability of farmers' satisfaction. This study employs manually to evaluate the level of user satisfaction.

3. Materials and methods

3.1 Description of the study area

The project area is found in the South Omo Zone of Southern Nations Nationalities and Peoples Regional State (SNNP) and Omo-Ratte the capital town of Dasenech Woreda, where the irrigation project is located is about 210 km from Jinka which is the capital town of South Omo Zone, 650 km capital city of Sidama Hwassa and 930 km from Addis Ababa. The Ratte Irrigation Project command area (10,000 ha) is located in the lower Omo-Gibe River Basin near Omo Ratte Town in Dasenech Wereda of South Omo zone, Southern Nations, Nationalities and Peoples Region The command area is located south of Omo Ratte town between $04^0 42'$and $04^0 50'$N and $36^0 00'$ and $36^0 10'$E, with an average altitude of 370 m.

3.1.1. Topography

The command area is generally suited for mechanized commercial farming due to its flat topography, which has slopes of less than 5% in most areas.

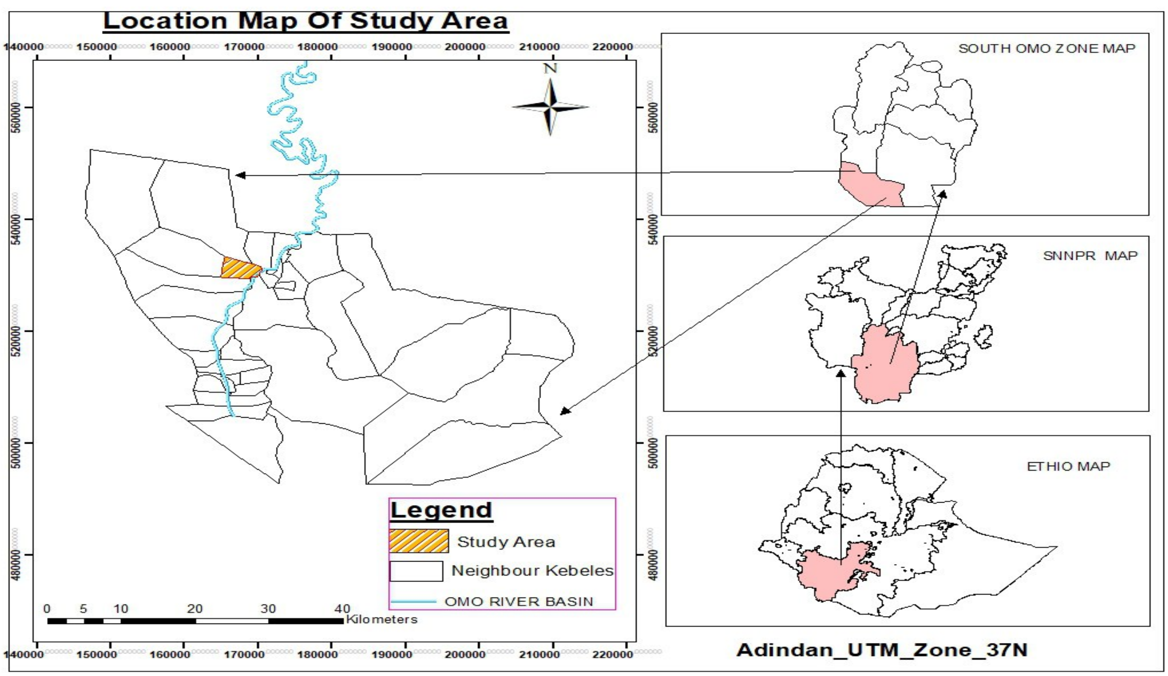


Figure 3.1. Location of the study area

3.1.2. Climate

Distinctly, the southwestern part of the low-lying areas of the Omo-Gibe basin has high rainfall, but the area near to Ratte Command area receives very low rainfall, as is the case in most lowland parts of Ethiopia. Regarding temperature, the mean annual temperature range around Omo-Ratte is 38-42 ^{o}c and the average temperature of the command area is 32 ^{o}c. According to the information obtained from the private commercial farm called FRI-EL, ETHIOPIA PLC. (Previously part of the Ethio-Korian farm) the Evapotranspiration in the area is about 7.86 mm per day.

According to the information obtained from Dasenech Woreda Agriculture and Rural Development office in Omo-Ratte town, the mean annual rainfall received in a given season is about 350 mm. In general, the amount and distribution of rainfall in Omo-Ratte is very erratic in terms of onset, amount, and distribution. In most cases, the number of rainy days in a given season is not more than ten to fifteen, and hence drought conditions prevail frequently and the rainfall condition in the area is not very reliable for successful crop production. (F.W.W.D.S.E.2010.)

3.1,3. Soil condition

The project area is found in the low-lying flat bottom land and the soil is generally an alluvial deposit washed down from the surrounding mountains and hills and deposited on the bottom land over a long geologic period as a result, it has a reasonably good natural fertility status in general. A detailed soil survey study in the command area has been conducted by the soil survey team and a comprehensive report has been produced for future reference. According to the result, there are two major soil types occurring in Ratte command area and these are fluvisol and vertosol which constitute 11011.6 Ha. (81.9 %) and 2434.6 Ha (18.1%) respectively.

The report further explains that both soil types exhibit desirable physical, chemical, and biological properties and with the adoption of proper management practices, the stated soil types have tremendous potential for increased and sustainable crop production. Soil depth in general is more than 2 meters in most part of the command area, which is ideal for mechanized irrigated agriculture. The drainage condition of the soils in most cases is moderate to well-drained with very minimal risk of water logging problems. Furthermore, it has been indicated that soil salinity-associated problems in these soils are minimal which make them suitable for crop production purpose.

According to the soil survey and analysis result soil reaction (PH) in both cases range from 6.4 to 8.9 which implies that the soils have slightly acidic to strongly alkaline soil reaction in general. The soil reaction range indicated here is in the optimum range for the proper growth and development of most crops selected for Ratte Irrigation project. However, it is advisable not to include crops that are sensitive to alkaline soil reactions in the production system in general. Generally speaking, low soil reaction (Acidic) can result in a reduced availability of Phosphorus elements due to fixation problems, and high soil reaction (Alkaline) may markedly hamper the Nitrification/Denitrification process of organic matter thereby resulting in reduced availability of some micro-elements. In general, it is important to adopt appropriate management practices such as the use of lime, choice of suitable crop types, and application of both organic and inorganic fertilizers preferably based on soil test results are recommended in order to ensure increased and sustainable crop production in the command area (F.W.W.D.S.E.2010.)

3.1.4. Land use pattern of the area

The area belongs to Semi-arid; hence, the natural vegetation of the area is semi-arid lowland vegetation types. The natural vegetation type and ground cover relatively follow certain patterns depending on soil types, soil depth, drainage pattern, etc. Mainly three types of vegetation cover; - namely cultivated land (employing hoe-based plow for the cultivation of maize crops using the aftermath of the Omo river overflow), open bushland, and grassland are identified over the command area. The cultivated land is very small covering an insignificant proportion of the entire command area, but the open bushland and grassland cover much of the command area (F.W.W.D.S.E.2010.)

3.1.5. Hydrology of the study area

From a hydrogeological point of view, The Omo Turkana depressions adjoining the Hamer Koke highlands are filled with thick (often reaching 3 km) alluvial lacustrine sediments. The continuation of sedimentation into the Holocene left its traces in the Omo delta whose geomorphic manifestations are still visible. Regardless of the presence of primary porosity and permeability associated with some components of the sediments of the Omo Turkana basin, the geochemistry of groundwater contained in the Omo sediments is very complex. Freshwater groundwater lens systems can be found interfingering with brines and brackish groundwater. The rocky outcrops within the Omo-Ratte River Valley are the crystalline basement of various granites, gneisses, and pegmatite, and when weathered in some areas have little significance to the storage and circulation of groundwater due to limited aerial extent and aquifer productivity from available water level data measured on the field from the existing few shallow wells, it has been observed that the groundwater level in the project area varies from 4.5m to 11m below ground level. Under the current investigation and available data, the trend and pattern of the water table beneath the command area is not fully understood due to the water level data gaps.

The groundwater level in the command area was discovered to be 7.5 meters below the surface, based on measurements made during the field survey. Unconsolidated alluvial sediment made up of sandy clay soil makes up the command area. According to a soil survey, this kind of sediment has a high infiltration rate of 0.79 meters per day. Thus, the groundwater level rise rate is estimated to be 0.54 meters per year based on these facts. Based on the groundwater data that will be gathered from the drilling and testing of test wells, this estimate needs to be updated. This level rise of 0.54 million per year is high at this study level. (F.W.W.D.S.E. 2010).

3.1.6. Major crop types and production practices in the area

Cereal pulses oil seeds and to some extent, fiber crops (mainly cotton) are grown in the target area. Cereals are the most dominant grain crops grown under the *Omo-Shesh* cropping system and these are planted in September and harvested in December. The major cereal crops grown in the area are Sorghum and Maize. Pulses like Haricot Bean are also grown and they are usually intercropped with Maize and Sorghum. Source**:** Dasenech Woreda Bureau of Agriculture and Rural Development.2022/09.

Figure 3.2. The Main water source for te Irrigation scheme

3.2. Sample size and sampling procedure

The selection of the study area were Dasench district and the scheme site is carried out purposefully, because of the relative accessibility of the district and the site. In the sampling design, the measurement locations were selected nearly at equal segments by simple random sampling techniques. The main canal was selected to evaluate the water delivery and conveyance performances at the head, middle, and tail reach of the main canal. Similarly, the flow measurements were taken on the Main, Secondary and tertiary which are located at the head, middle, and tail reach of the irrigation system in part for collecting the flow data. Whereas, measurements at tertiary canals were taken only at the head and tail reach of each canal because tertiary canals are shorter canals by length.

Infiltration of the soil was measured at three points at the head, middle, and tail end of the irrigated land of the scheme. The scheme capacity as it stands at present ease of use and functionality of the scheme water management systems were explained clearly. In addition to this representative of users was taken randomly as a base for HH selection for an interview (based on canal location) since the view of users are different not only in each village but also in each canal location in the scheme using random selection among the resident irrigation users were interviewed to assess their experience and way of the utilization of the irrigation schemes' by using a questionnaire. from the total beneficiaries in the selected command area, the representative sample size was determined using simplified Equation 3.1. Finally, the representative respondents were selected randomly. Yamane (1967) provide

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

Where: n = Sample size, N = Population size or total irrigation users, e = Level of precision Based on this formula a total of 48 respondents' representative of irrigation users was selected.

$n=\frac{48}{1+48(,1)2}=32$ A simple random sampling technique was used to select male and female respondents from each canal reach.

3.3. Methods

3.3.1. Data sources and data collection

The required data were collected from both primary and secondary sources using internal indicators. The primary data were collected from the field by direct measurement such as; discharge, soil infiltration rate, perception of users using questionnaires, and field observation of irrigation infrastructures. Whereas, secondary data were collected from different offices and design documents.

3.3.1.1. Primary data

Actual field investigation and measurements or survey works, including simple observations of the scheme at the site, were required to collect the necessary data to know the present condition of the scheme. The important data for the study includes: -

- Infiltration rate of the soi
- Discharge measurement of the scheme system
- Field observations were taken to observe and investigate the status of the scheme
- Focus group discussion and key informant interview

3.3.1.2. Secondary data

The secondary data for the site were gathered from historical reports and files maintained by accountable agencies like the Aleketekech Kebele office, the Jinika Meteorological Station, the Pastoral Affairs Bureau of SNNPR, and the Bureau of Agriculture and Rural Development Office of Daseneche Woreda.

Table 3. 1. Materials and software used for sample collection and analysis

No	Material type	Purpose
1. Material		
1.1	Measuring tape (50m)	To Measure the dimension layout of the farm
1.2	Stopwatch or clock	To record time
1.3	Floating object	Floating material (Flow velocity measurement)
1.4	Staff gauge	To insert it to measure water depth
1.5	GPS	To collect different coordinate points
1.6	Double ring why this	To measure infiltration rate of soil
1.7	Hammer	To hit the core sampler
1.8	Stakes	To fix the measuring place
2. Software		
2.1	Arc GIS 10.8	To work map of the study area
2.2	Cropwate8.0 model	To analyses ETo, CWR, and Crop schedule

3.4. Data analysis

The aim of good irrigation management is to obtain a correct flow division within the canal network and over the fields. This means that discharges in canals should meet the demand for water from the farms. A poor flow division may result in discharges being too high in some canals and too low in others, which could lead to water disputes between farmers. To achieve sufficient and equitable delivery of water to the fields, it is useful to evaluate and analyze the gap, which is very important. So based on this, the collected data were summarized and analyzed.

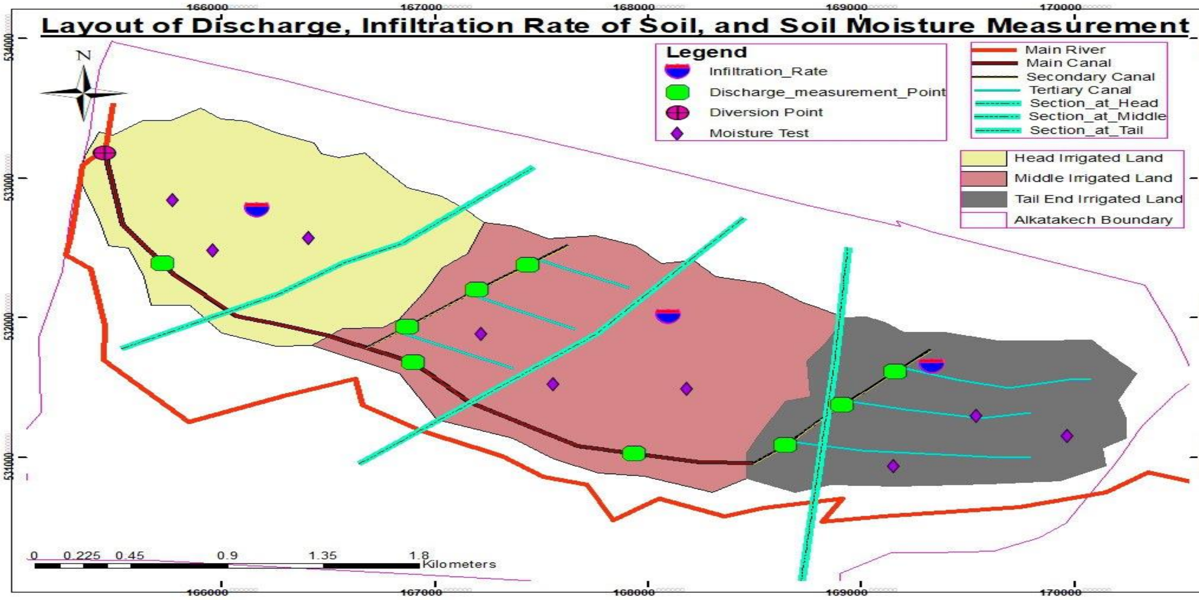


Figure 3.3. Layouts for Discharge, Infiltration rate of soil, Soil moisture teste measurement

3.5. Infiltration rate

Soil and water are the vital natural resources used in the crop production system. Efficient management of water will be required a greater control of infiltration in the soil. Increased infiltration control would help to solve such wide-ranging problems as upland flooding, pollution of surface and groundwaters, declining water tables, inefficient irrigation of agricultural lands, and wastage of useful water (Rashidi, Ahmadbeyki, &Hajiaghaei, 2014). Soil infiltration rate is the most essential process that affects the surface irrigation uni-formity and efficiency because of its mechanism of transfer and distributes water from surface to soil profile (Rashidi et al., 2014).

Cumulative infiltration (f(t)) is the total amount of water that soil strata are able to absorb from irrigation or rainfall in a given time; infiltration rate (f(t)) is the velocity of the water entering the soil in a given period of time. (December 2021, Mahdi Panahi and Khabat Khosravi).

The measurement of infiltration of water into the soil is an important indi- cation concerning the efficiency of irrigation and drainage, optimizing the availability of water for plants growth and metabolism, improving the yield of crops and minimizing erosion (Adeniji, Umara, Dibal, & Amali, 2013). Adequate knowledge of infiltration rate of a soil data is essential for reliable prediction and control of soil and water related environmental hazards. Prediction of cumulative infiltration is impor tant for estimation of the amount of water entering and its distribution in the soil.

To determine the infiltration rate of the soil in the scheme, double ring infiltrometers of 30 cm and 60 cm inner and outer ring diameters respectively were used at the selected representative of the scheme which have different soil textures. The double ring infiltrometer was driven up to 15 cm depth depending on the soil depth of the site by a hammer. A minimum head of 12 cm was maintained in both rings during measurement. Depths to water levels were measured at increasing time intervals from the datum established on the edge of each cylinder (Johnson, 1991). In the study infiltration rate was measured using double ring infiltrometer at 3 representative sites was taken where at head, middle and tail end of the irrigated land. The procedure followed for carrying out the infiltration rate tests in the field is discussed below:

- Both the cylinders were driven into the soil to approximately 15 cm depth, by placing the driving plate over the cylinders and hammering with a heavy standard hammer,
- Water was filled first into the outer cylinder immediately followed by filling water into the inner ring to the same depth. This reduces the horizontal hydraulic gradient and water flows vertically into the soil.
- Readings were taken on the fall of the water head with respect to time in the inner ring using hook gauge/float and stop watch. The same procedures were repeated to the other replicates,
- The readings were recorded in a standard format and the rates were calculated,
- After the completion of infiltration tests, the rings were taken out and wetted depth was measured,
- The curves of infiltration vs. time were plotted on log-log graph paper and the

- cumulative infiltration and infiltration rate as shown in the (Figure 3.7) sheet were computed. From the graphs, the values of the maximum initial and basic infiltration rates were obtained.
- The computation and plotting of infiltration rate data for all are separately given in the (appendices A)

Figure 3.4. Soil infiltration rate of the soil taken of the study area

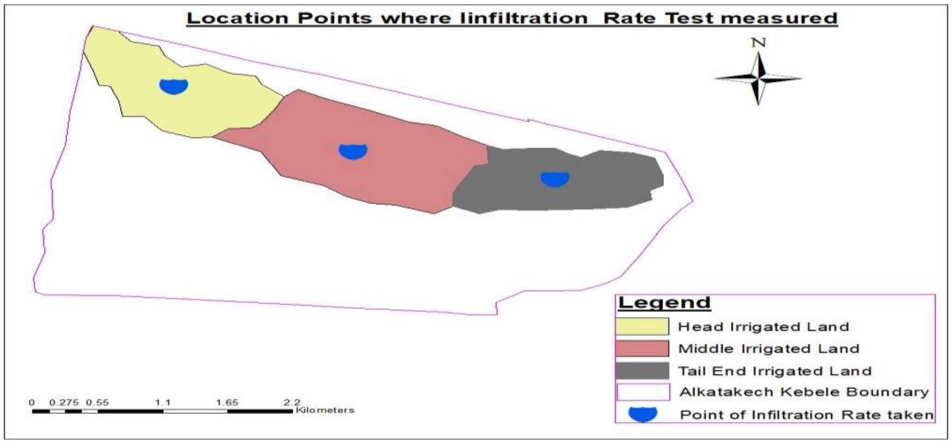


Figure 3.5 point of soil infiltration taken

3.6. Discharge measurement

The float method for the main canal and the Parshall flume for field application water were used to calculate the irrigation water discharges from the irrigation scheme that were diverted from the Omo River diversion. One of the primary tasks of data collection is flow measurement. Understanding distribution uniformity, application and conveyance efficiency, and storage efficiency are helpful. The main canal of the scheme was measured through flow measurement.

The Parshall flume, a vertical throat in an open channel that is horizontally constricted and used to measure the discharge entering a field (sample) plot, was used to measure the water application of the primary, secondary and tertiary canals. Due to the lack of additional materials, the canal discharge was measured using the area-velocity method (current meter). First, choose a straight section of the canal that is at least 10 metres long. The canal's shape should be as uniform as possible. Place two stakes, one on each side, at the upstream end of the selected portion of the canal these stakes should be perpendicular to the canal's centre line. Measure at least 10 metres along the canal. Place two stakes at the downstream end of the selected section of the canal, likewise perpendicular to the canal's centre line at least 10 metres upstream of the point.

Throughout the trial, the object should not come into contact with the canal embankment; if it does, the operation needs to be redone, and the duration of the unsuccessful trial shouldn't be factored into the average time calculation. Using the equations $Vs = L / t$, where t is the travel time in seconds based on the average of four clear runs of the floating object, and $V=0.85*Vs$, Measure the canal cross-section at the chosen canal section. Next, calculate the surface velocity, Vs, and finally the average flow velocity, V (Harrelson, 1994). is a constant coefficient of velocity reduction. FAO (1985–1993) used this as a way to reduce the mean velocity of the turbulent flow. The relationship with the depth of flow were another reason. So, my canal depth was in the range of the corresponding correction factor and then: -

- Calculate the wetted area of the cross-section
- Calculate the discharge, Q, in the canal, Q = V * A Where Q in m^3/s By following the above procedures discharge measurements at the main canal using floating material were done
- First along a straight line and uniform section was selected a 10 m long with an average top width of 0.4m along the canal in which the float object traveled. The average depth of flow water was measured. The floating object was released slightly into the center of the beginning section of the canal and then a stopwatch were used to measure the elapsed time
- This measurement was repeated three times to be more accurate and the result of the measured discharge is shown in (Appendices B Table). The discharge in the canal was measured with a floating method. The method consists of estimating the average flow velocity which was taken from three points at the head middle and tail respectively. A total of nine points were taken and the area of the cross-section, called the Wetted cross-section". was measured.

The discharge was calculated by continuity equation 2 (Yoder 1999.) The average area was calculated using the equation described by (Yoder 1999)

A= b*h ---3.2

Where A is the area of the canal, b top width of the canal, and h is the depth of water.The average flow velocity (V**)** To estimate the average flow velocity, the flow velocity of the water at the surface, the surface velocity, Vs were first determined. The surface velocity was determined by measuring the time it takes for a floating object along the canal. The floating object was placed in the Centre of a canal *and* the time measurement was repeated three times. To determine the velocity of the surface water of the channel, the length of the trail section was divided by the average time taken by the float cross it Since the velocity of the float on the surface of the water is greater than the average velocity of the stream, it was necessary to correct the measurement by multiplying a constant factor (velocity correction factor) which was usually assumed to be 0.85 (Harrelson, 1994).To obtain the rate of flow, this average velocity (measured velocity * correction factor) was multiplied by the average cross-sectional area of the stream. To compute the surface velocity, Vs the selected length, L was divided by the travel time, t:

$V = \frac{L}{T}$ ---3.3.

Where L is the length of float material traveled and T is the time taken for the floating material to reach the end section. The flow discharge, (Q) (m3/s) in the canal, was calculated using the formula below

Q = V*A --3.4.

Where Q is the flow discharge in m^3/s V is the average flow velocity and A cross-section of the canal Area of The Wetted Cross Section For measuring the flow with the floating method, the area of the wetted cross-section (A) was determined for a selected straight and uniform portion of the canal.

the canal was trapezoidal and the area was calculated from measurements of the bed width (b), the width of the surface water (a_1), and the water depth (h_1) (P.K. Swamee.2015)

$$A = \frac{(b+a1)}{2} \times h_1 \text{------------------------------}3.5$$

Where A =is the wetted cross section (m^2)

b = is bed width

a= is surface water width

h_1 =is the water depth

Determination of the losses

The conveyance efficiency in irrigation projects is poor due to seepage, percolation, cracking, and damaging of the earth channel. Seepage loss in irrigation water conveyance system is very significant, as it forms the major portion of the water loss in the irrigation system. Irrigation conveyance losses controlled through lining may reduce the drainage requirement and also enhance irrigation efficiency.

As such, reliable estimates of quantities and extent of seepage losses from canals under pre- and post-lining conditions become important. Various methods are used to estimate the canal seepage rate. The loss in conveyance is unavoidable unless the canal is lined. Lining may be done with a large variety of materials. Selection of a suitable one depends mainly on cost, performance, durability, and availability of lining materials. (M.H.Ali November 2010

Conveyance Losses Conveyance losses are affected by number of factors such as depth of water, quality of channel lining, channel dimensions, bed slope, volume of sediment, age of channel, volume of flow, velocity of flow and the quality of operations and maintenance of water channels Conveyance losses in this study were simply computed by subtracting obtained conveyance efficiency at each reference point from 100 Mathematically (N.B. October 2021)

Conveyance losses = 100 − Conveyance efficiency---3.6.

3.8. Internal performance indicators

The internal performance indicators for the irrigation scheme were computed based on field measurement data. The internal performance indicators used to evaluate were:

3.8.1. Water conveyance efficiency (Ec)

The water conveyance efficiency of the canals were estimated by measuring inflow and outflow or The percentage of source water that reaches the field for the selected canal reaches. The average values of inflow and outflows for all measurements for each of the selected canals were used for the estimation of water conveyance efficiency (Michael, 1986.)

Ec = 100 (Wf / Ws) --3.7.

Where

E_c=Water Conveyance efficiency in%

Wf = Water delivered to field(l/s)

Ws = Water diverted from source(l/s)

3.8.2. Water application efficiency

Application efficiency (Ea) was measured by calculating the ratio of the depth of water stored in the root zone during irrigation to the depth of water diverted into the field (Michal, 2008). Water application efficiency is described as a percentage of water delivered to the field that is consumed by the crop, computed as follows: (Mati, 2011).

$$Ea = \frac{Ws}{Wf} x100 \text{--} 3.8.$$

Where

Ea is application efficiency (%), y

Ws = water stored in the root zone of the plants

Wf = Water delivered to the irrigated plot (At the field supply channel).

3.8.3. Storage efficiency

According to (Jurriëns, Zerihun, Boonstra, & Feyen, 2001). adequacy or storage efficiency is the measure of how close the applied amount is to the apparent requirement (the right amount) over the entire subject region and is defined as the ratio between the amounts actually stored in the subject region to the required amount. The adequacy of an irrigation turn expressed in terms of storage efficiency, which is defined as the ratio between the storage depth and the required depth (Jurriëns et al., 2001).

Based on the moisture content at field capacity, permanent wilting point and bulk density of the soils of the selected irrigation fields and the root depth of the crop irrigated, the depth of irrigation water required by the crop planted in the study area was calculated (Allen et al, 1998). After determining the storage and the required depth, the storage efficiency was computed as follows (Hassen,2004).

$$E_S = \frac{Ws}{Wn} X100 \text{--} 3.9$$

Where

E_S = is storage efficiency (%),

W_S =is depth of water stored in the root zone and

W_n is depth of water required to be stored in the root zone and it is 75% of TAW.

Important soil characteristics in irrigated agriculture include: (1) the water-holding or storage capacity of the soil; (2) the permeability of the soil to the flow of water and air; (3) the physical features of the soil like the organic matter content, depth, texture and structure; and (4) the soil's chemical properties such as the concentration of soluble salts, nutrients and trace elements The total available water, TAW, for plant use in the root zone is commonly defined as the range of soil moisture held at a negative apparent pressure of 0.1 to 0.33 bar (a soil moisture level called 'field capacity') and 15 bars (called the 'permanent wilting point'). The TAW will vary from 25 cm/m for silty loams to as low as 6 cm/m for sandy soils. (FAO 1989)

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 calculated from the moisture content in volume percent at field capacity and permanent wilting point (Allen, Pereira, Raes, & Smith, 1998).

$TAW(mm) = 1000*(Fc – PWP) *Z_r$---3.10.

Were, TAW - Total available water in the root zone (mm)

Fc = moisture content at field capacity (m3/m3) this found from result

PWP = moisture content at permanent wilting point (m3/m3) and

Z_r = the root depth (m)

3.8.4. Distribution uniformity

To determine the distribution uniformity of irrigation water in the selected farmer's field augur samples were taken from the selected points. Soil samples were collected from different depths with an interval of 30cm up to 90cm. Then the soil moisture contents of the soils at the selected points were analyzed to determine the depth of water distribution. Distribution uniformity was defined as the minimum infiltrated depth divided by the average infiltrated depth (Jurriens et al, (2001)

$DU= \frac{Mnimum\ depth\ (cm)}{Average\ debth(cm)} X\ 100$---3.11

Where,

DU = water distribution uniformity (%),

Dmin= minimum accumulated soil moisture depth this is determined from soil moisture after irrigation and

Dav= the average accumulated soil moisture depth (mm).

3.8.5. Overall efficiency

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

$E_o = E_c * E_a$ --3;12

Where

E_o =is overall scheme efficiency (%),

E_c =is conveyance efficiency (%) and

E_a= is application efficiency (%)

A. Irrigation ratio

The intensity with which the irrigated area is cropped traditionally is a function of the number of crops per year grown on an irrigated area.

$$IR=\frac{Irrigated\ area}{command\ irrigable\ area} \text{---} 3.1$$

B**. Sustainability of irrigated area**

According to Bos (1997) sustainability of irrigated area is the ratio of currently irrigable area to initially irrigated area.

$$SIA = \frac{\text{Currently irrigable area}}{Initially\ Irrigated\ area} \text{--} 3.14$$

3.9. Determination of reference evapotranspiration (ETo)

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

3.10. Crop water and irrigation water requirements

Crop water and irrigation water requirements were calculated using CROPWAT 8.0 model. The detailed crop water and irrigation water requirements of major irrigated crops such as maize, Haricot bean, onion, sorghum and ground nut respectively in the irrigation scheme were indicated (From table4.3-4.7.)

Irrigation scheduling

The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. The amount of water applied is determined by using a criterion to determine irrigation needs and a strategy to prescribe how much water to apply in any situation Hence the importance of irrigation scheduling is that it enables the irrigator to apply the exact amount of water to achieve the goal. This increases irrigation efficiency. Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper scheduling is essential for the efficient use of water, energy, and other production inputs, such as fertilizer. It allows irrigation to be coordinated with other farming activities including cultivation and chemical applications.

FAO (1989) explained that when surface irrigation methods are used, however, it is not very practical to vary the irrigation depth and frequency too much. In surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change their schedules all the time. Therefore, it is often sufficient to estimate or roughly calculate the irrigation schedule and to fix the most suitable depth and interval, to keep the irrigation depth and the interval constant over the growing season. of several methods to determine when to irrigate, the Water budget method is more commonly applied this day.

3.12. User satisfaction

Farmer's perspectives and assessments of irrigation scheme performance are critically inherent for irrigation system management. Dasenche irrigation scheme is indeed expected to play a vital role to realize food security and enhance farm incomes in the rural households. Yet, insufficient farm returns and social factors corresponding to water distribution problems are transpired. The objective of this study was to assess the level of user's satisfaction with irrigation services provided by the scheme in terms of, equity of water distribution, timelines of water delivery, user's contribution in operation and maintenance activities; operation and maintenance requirements of the system.

4. Result and discussion

Rate large-scale irrigation scheme characterization and performance evaluation was carried out using different resources characterization and efficiency indices and the results are presented and discussed in this chapter.

4.1. Infiltration rate

The infiltration rate measurements of the Ratte command area were conducted in three representative irrigated sites by making use of the Omo River, where the irrigation development of the current Ratte irrigation command area was used during the irrigation implementation. The mean infiltration rate test results as included in the database showed results 7.76 cm/min values in some cases which are different from standards, these results indicated that higher than the recommended ranged values for the same soil type reported by FAO (2001.) The maximum recommended value of the basic infiltration rate for clay soil is 0.5 cm/hr The reason might be there was a high temperature during the infiltration test that may have made the difference. The database of the infiltration test measured was found (Appendices. Table A)

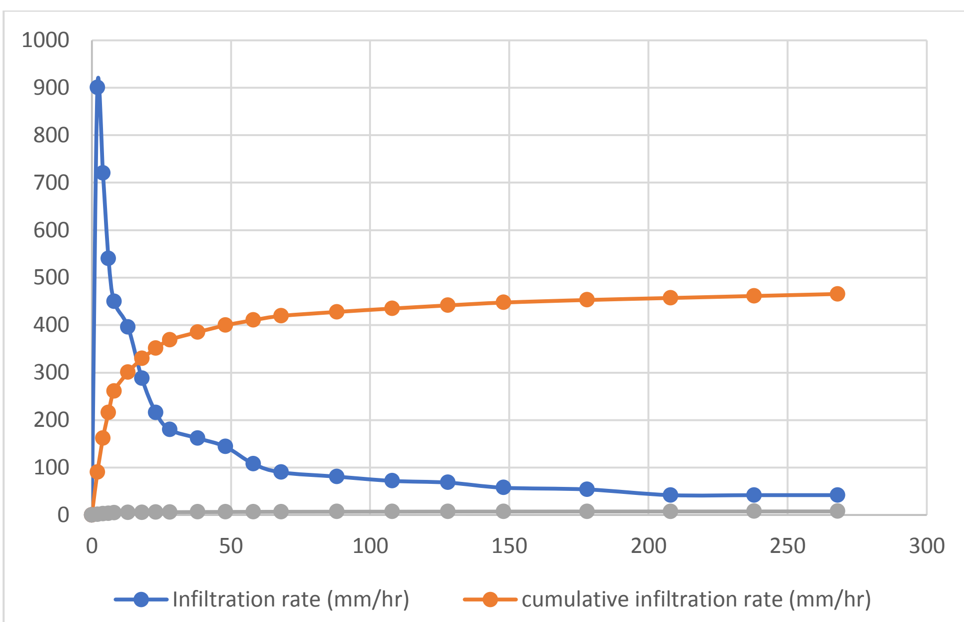


Figure 4.1Curve of infiltration rate with cumulative infiltration rate

4.2 Internal indicators

Even though, various authors have suggested many performance indicators, the types of indicators chosen depend on the purpose of performance Evaluation (Bos et al.,2005). In this study, on-field water management was assessed in terms of Conveyance efficiency, application efficiency, storage efficiency, and distribution uniformity. 57.3, 63.6, 88.17,78.38. Application efficiency Irrigation management can improve efficiency by 5-20% by applying the right depth of water in the right place at the right time (Rose, 2006). The calculated application efficiencies of the three canals reaches were in the range of 62.64– 65.3%, which indicated that the farmers were applying water to their fields (Table 4.6) This result was in line with Roger et al.(1997) reported as it is possible to have high

application efficiency (50- 90%) that can be used for general system type comparison and Lesley (2002) report as it could be in the range of 50-80%. But the result was disagreed with FAO (1989) that reported that the maximum attainable application efficiency ranges from 55%-70%. Farmers were applying excess amounts of water to their fields without considering the water requirement of the crop. From the result, as we could see, the distance of the farm from the water source never limits the irrigation users to apply water.

4.2.1. Conveyance efficiency and losses

The irrigation scheme had been only main, primary, secondary, and tertiary canals. so that conveyance efficiency and losses were determined for main and tertiary canals. The calculated main ,secondary and tertiary canal efficiencies were 93%,82, and 70% respectively as indicated in (Table 4.1) The conveyance efficiency of the scheme would be the product of main, and tertiary canals which were 57.3%. The average value was below FAO (1989) recommended values greater than 2000 meters canal length earthen canals in loam sandy soil of conveyance efficiency should be 80%. As a result, the conveyance efficiency of Rate large-scale irrigation scheme was poor. The major causes of high-water loss or low conveyance efficiency were seepage, because of high temperature of the study area cause high amount of evaporation, and malfunctioning control gates. This inefficient conveyance affected the equity of water distribution throughout the systems; particularly the tail users did not get their equitable share within the required time.

Table 4.1 Calculated conveyance efficiencies and losses

Canal	Conveyance efficiency %	Conveyance loss l/s/m
Main Canal	93	0.07
Secondary canal	80	0.20
Territory canal	77	0.23
Average Conveyance efficiency		

4.2.2. Application efficiency

However, the study area was practiced back furrow irrigation and the data for discharge were taken at Head, Middle, and Tail field locations respectively for the irrigation scheme The application efficiency was estimated using equation 3.8 and presented in (Table 4.4). The values for the three locations (head, middle, and tail) of the irrigation scheme were in the ranges of 64.9 to 65.3 % with an average of 62.6 %. The application efficiencies were vary from field to field. The head and the middle irrigation schemes were more efficient than the tail-end irrigation schemes due to short furrow length, short application time, and proper water management. While at the tail-end irrigation scheme, the furrows were long, improper furrow layout and excess application time were used and due to this, the tail-end irrigation field was less efficient relative to the head and middle irrigation fields. As FAO (1989) water application efficiency for furrow irrigation method ranged 60-70%. Whereas according to Rogers et al. (1997) revealed that furrow irrigation methods have a wider range of application efficiency i.e., 50-90%. On the overall basis, the values of application efficiency for the study area were indicated as somewhat efficient. This is due to the shortage of water availability from the source and the farmers tried to apply less water wisely to their fields.

Table 4.2 Application efficiency

Canal reach	Applied depth in mm	Stored depth in mm	Application efficiency (Ea) %
Head	168.7	109.6	64.9
Middle	164.4	107.5	65.3
Tail	162.6	105.8	62.64
Average Application efficiency			63.6

4.2.3. Storage efficiency

The adequacy of an irrigation event is expressed in terms of water requirement (storage efficiency). Storage efficiency has the advantage of knowing the applied irrigation water has satisfied the moisture deficit of the crop root zone. It is the most directly related to the crop yield since it will reflect the degree of soil moisture stress. Usually, under-irrigation in high-probability rainfall areas is a good practice to conserve water but the degree of under-irrigation is a difficult question to answer at the farm level (Walker, 1989). As shown in (Table 4.7.). The average storage efficiency of the scheme was 88.17% and a nearly similar result was reported by Tedla (2007) at Bullinegero Large -scale irrigation scheme which was 92.8%. Depending on the weather, type of soil, and time considered, storage efficiency might be as high as 90% (FAO,1992)

Table 4.3. Storage efficiency

Canal reach	Stored water at root zone in mm	Required water in mm	(Es) %
Head	109.6	123.0	89.10
Middle	107.5	122.2	87.97
Tail	105.8	121.0	87.44
Average Storage efficiency of the scheme			88.17

4.2.4. Water Distribution Uniformity

The distribution uniformity describes how evenly irrigation is applied to the crop. There was high distribution uniformity at middle and Head field users than at Tail irrigation fields While at the tail end irrigation scheme the furrows were due to short furrow length, short application time and un proper water management were used and due to this the tail end irrigation field was less efficient relatively to the head and middle irrigation fields. which were range 78.9-80.07 (Table 4.8). The average distribution uniformity was78.38 %

Table 4.4. Distribution uniformity

Canal reach	Mean stored water in mm	The least quarter mean stored water in mm	DU %
Head	109.6	87.76	80.07
Middle	107.5	84.4	78.9
Tail	105.8	80.6	76.18
Average distribution efficiency of the scheme			78.38

4.2.5. Deep percolation ratio

Since farmers were practicing closed end furrow, only deep percolation was considered. The magnitude of deep percolation loss varies with the type of crops grown. Crops with high application efficiencies had lowest DPR value and vice versa. In this study Average loss due to deep percolation was 35.7.% as indicated in (Table 4.9) because of excess application of water before water depleted from the root zone. A higher deep percolation naturally results lower application efficiency (FAO1992.)

Table 4.5. Parameter and calculation for deep percolation ratio

Canal reach	E_a (%)	DPR
Head	64.9	35.1
Middle	65.3	34.7
Tail	62.64	37.4
Average		35.7

4.2.6. The overall scheme efficiency (E_p)

The calculated overall efficiency of the irrigation scheme was 49.5% as indicated in (Table 4.6). This result implied that the scheme was performed with low efficiency. The overall scheme efficiency at the study area was obtained to be49.5%. This result indicated that the overall irrigation efficiency is in efficient as compared with values ranged 50 -60% stated by FAO, (1989) for surface irrigation. This l value is below the standard due to their secondary and tertiary canals at the irrigation scheme and also high-water loss dut to high temperature of the area. Therefore, no losses from secondary and tertiary canals. The overall Scheme efficiency (Ep)

Table 4.6. Overall efficiency

Indicators	The efficiency of the scheme In%
Conveyance efficiency	57
Application efficiency	63.6
Storage efficiency	88.6
Distribution efficiency	78.38
Deep percolation	35.72
Overall efficiency	36.32

A. Irrigation ratio

The irrigation ratio of the scheme was 0.025 which means 2.50% of the command area was currently irrigated and about 97.5% of the command area was fallow during the study period as shown in (Table 4.7)

B. Sustainability of irrigated area

As shown in table 4.16 the computed values of sustainability of irrigated area at the study scheme were found to be 52% which indicates the current irrigable area is becoming increasingly the irrigable area compared to at the initial period of the irrigation scheme.

Table 4.7 Physical performance indicators computed values

Command Area /ha/	Initially irrigated Area/ha/	Currently irrigated area/ha/	Irrigation ratio IR (%)	SIA in (%)
10000	131.8	250	2.50	52

4.3. Determination of reference evapotranspiration (ETo)

Evapotranspiration (ETo) is the simultaneous process of transfer of water to the atmosphere by transpiration and evaporation in a soil–plant system (Rosenberg et al., 1983; Allen et al., 1998; Mavi and Tupper, 2004). In an agricultural field, when the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and the canopy completely covers the soil, transpiration becomes the main process of water loss. ET is an important parameter for climatological and hydrological studies, as well as for irrigation planning and management. Evapotranspiration (ET) is the simultaneous process of transfer of water to the atmosphere by transpiration and evaporation in a soil–plant system (Rosenberg et al., 1983; Allen et al., 1998; Mavi and Tupper, 2004). In an agricultural field, when the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and the canopy completely covers the soil, transpiration becomes the main process of water loss. ET is an important parameter for climatological and hydrological studies, as well as for irrigation planning and management.

The variation of the monthly mean value of reference evapotranspiration, effective rainfall, and rainfall was indicated in (Table 4.8). The ETo value from January to March and September to December was larger than the corresponding values of effective rainfall but smaller values from June to August. The maximum and minimum ETo values were 7.58 and 7.37. mm/day in April and July respectively. The monthly ETo values for the study period from February to May 2022 were 8.68, 8.31 , 7.22, and 7.17 mm/day respectively. The monthly mean ETo value from January to December was 7.95 mm/day. However, the monthly average ETo value for the study period was 7.86 mm/day. The result shows how the area was warm and great evapotranspiration apprehended.

Table4.8 Climate data and reference evapotranspiration

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	23.4	37	40	310	9.5	22.5	8.01
February	23.7	38	41	340	9.5	23.5	8.68
March	23.7	38.1	43	330	7.6	21.3	8.31
April	22.1	35.7	49	270	8.8	22.9	7.22
May	22.5	35.5	50	300	8.6	21.8	7.17
June	22.5	35.4	47	320	8.5	21	7.37
July	21.7	34.9	45	330	8.1	20.6	7.45
August	21.7	34.8	44	330	8	21.2	7.58
September	22.5	36.2	41	360	9	23.2	8.54
October	22.7	36.5	46	360	9.2	23.1	8.25
November	22.6	36.3	43	350	8.9	21.7	8.07
December	22.7	36	44	330	9.5	22	7.74
Average	22.6	36.2	44	328	8.8	22.1	7.86

Rainfall data analysis

Rainfall also determines the potential of any region in term of crops to be produced, farming system to be adopted, the nature and sequence of farming operations to be followed and to achieve higher agricultural productivity as well. Irrigation water requirements are particularly abundant in the works under several surfaces, crop water requirements, crop yield and evapotranspiration as influenced by water accessibility, crop water modeling and irrigation scheduling techniques. Therefore, Double mass curve technique is more reliable for analysis of rainfall data to check the consistency. Then this consistent data and ETo through CROPWAT model can be utilized to estimate the contribution of rainfall towards crop water requirement to determine that how much irrigation is required to enhance the productivity. (Tahir Saeed Laghari, Abdul Khaliq, December 2014).

Mean monthly rainfall profiles were generally with peak April as shown in (Table 4.9.) Rainfall is conditioned principally by migration of Tropical Convergence Zone which accounts for almost 40% of annual rainfall on average between March and October

Table 4.9. Rain fall data of Omoratte

Month	Rain mm	Eff rain mm
January	0	0
February	0	0
March	46	17.6
April	53	21.8
May	27	6.2
June	11	0
July	20	2
August	45	17
September	23	3.8
October	29	7.4
November	17	0.2
December	10	0
Total	281	76

A. Net Crop water requirement (CWR) and net irrigation requirement (IR)

Net crop water requirements (NIWR) are the total amount of water needed for crop growth over a year, which includes the sum of individual crop water requirements (CWR) for each irrigated crop. NIWR is expressed in millimeters per year or in m3/ha per year, where 1 mm = 10 m3/ha. It depends on the cropping pattern and the climate. and the net irrigation water requirement (INET) is the net amount of water that must be applied by irrigation to supplement stored soil water and precipitation and supply the water required for the yield of an irrigated crop (Mladen Todorovic 2006).

The net CWR and net IR were calculated for each crop for 2022/2023 irrigation season by CROPWAT 8.0 model based on the ETo a shown (Table 4.10). The Cumulative CWR and IR were estimated using Crop wat 8. described in obtained the total values of 86,678.25 and 264,807.59mm per growing season (January to December) respectively. The summary results of the net CWR and net IR for the five major crops (maize haricot bean, onion, sorghum and ground nut) of the study area are presented. The detailed data base of crop water requirement, irrigation requirement and other related charts that show the ETo, effective Rain fall data, readily total available moisture, depletion, and irrigation requirement in are shown (Appendices Table C, D, E, F, G,)

Table 4.10. Net Crop water requirement and irrigation requirement.

Crop Type	Area In/ha/	Effective Rain Fall mm/season	Net irrigation requirement mm/season	Crop water requirement mm/season	Total net irrigation requirement mm/season	Total crop water requirement mm/season
Maize	87.5	45.6	1174.8	817.9	102795	71566.25
Haricot bean	45.5	30.5	915.8	565.3	41668.9	25721.15
Onion	10.75	41.7	1080.4	653.2	11614.3	7021.9
Sorghum	90.25	45.6	954.6	732.9	86152.65	66144.225
Ground nut	15.85	28.1	1424.4	852.5	22576.74	13512.125
Total	250	191.5	5550	3621.8	264807.6	86678.25

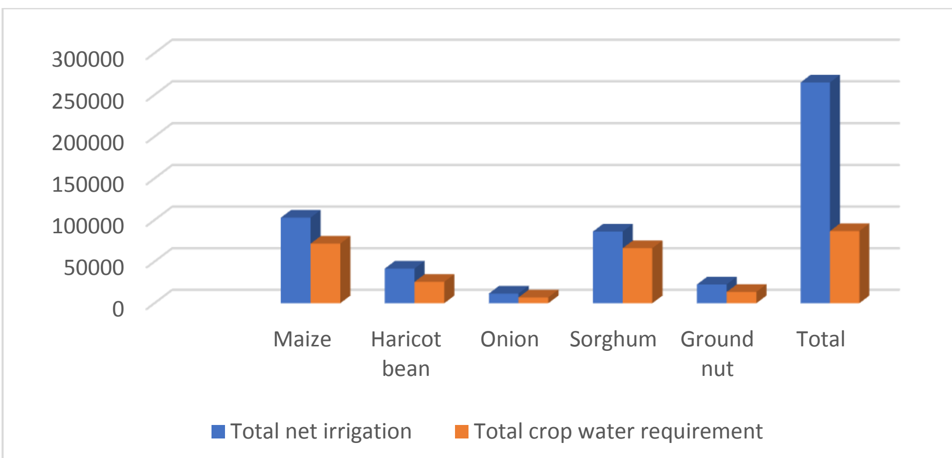


Figure 4.2. Comparison net irrigation requirement with CWR

Irrigation scheduling

The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. The amount of water applied is determined by using a criterion to determine irrigation needs and a strategy to prescribe how much water to apply in any situation. Hence the importance of irrigation scheduling is that it enables the irrigator to apply the exact amount of water to achieve the goal. This increases irrigation efficiency. Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper scheduling is essential for the efficient use of water, energy, and other production inputs, such as fertilizer. It allows irrigation to be coordinated with other farming activities including cultivation and chemical applications. FAO (1989) explained that when surface irrigation methods are used, however, it is not very practical to vary the irrigation depth and frequency too much. In surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change their schedules all the time.

Therefore, it is often sufficient to estimate or roughly calculate the irrigation schedule and to fix the most suitable depth and interval, to keep the irrigation depth and the interval constant over the growing season. of several methods to determine when to irrigate, the Water budget method is more commonly applied this day. Based on this the farmers practiced irrigation intervals were vary in some crops as indicated in (Appendix Table from C to G).

Farmers were applying the same irrigation interval in each growth stage of the irrigated crop but crops required different amounts of water at different irrigation intervals within each growth stage. But crops require different irrigation intervals in each growth stage because the requirement of water depends on the growth stage and other factors. As a result of applying the same irrigation interval throughout the growth stage, irrigated crop production would have declined.

Crop pattern

The optimal cropping pattern plays a crucial role in determining the productivity and sustainability of agriculture. Determining the optimal cropping pattern requires careful consideration of several factors, including climate, soil type, water availability, market demand, and crop suitability. Various analytical tools and approaches can be used to determine the optimal cropping pattern, including agronomic, economic, and ecological considerations. Strategies for planning and implementation of the cropping pattern include crop rotation, intercropping, sustainable soil management, and irrigation management. By following a holistic approach to agricultural planning, farmers and policymakers can make informed decisions that lead to sustainable and profitable agricultural practices. (C. P. Kumar,2020).

Table 4.11. Crop pattern

Precipitation deficit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. MAIZE (Grain)	268.7	304.3	196.4	2.6	0	0	0	0	0	0	7.2	95
2. SORGHUM (Grain)	0	33.8	111	198.5	222.6	109.3	0	0	0	0	0	0
3. Soybean	0	0	12.7	132.6	258.3	136	0	0	0	0	0	0
4. Small Vegetables	0	0	112.4	178.3	234.6	89.4	0	0	0	0	0	0
5. Groundnut	0	0	0	8.6	90.2	208.2	272.1	225.9	21.1	0	0	0
Net scheme irr.req. in mm/day	2.7	3.8	3.5	3.6	4.7	2.6	0.4	0.3	0	0	0.1	1
in mm/month	83.3	106.1	109.9	107	144.4	77.3	10.9	9	0.8	0	2.2	29.5
in l/s/h	0.31	0.44	0.41	0.41	0.54	0.3	0.04	0.03	0	0	0.01	0.11
Irrigated area (% of total area)	31	66	91	95	64	64	4	4	4	0	31	31
Irr.req. for actual area (l/s/h)	1	0.66	0.45	0.43	0.84	0.47	1.02	0.84	0.08	0	0.03	0.35

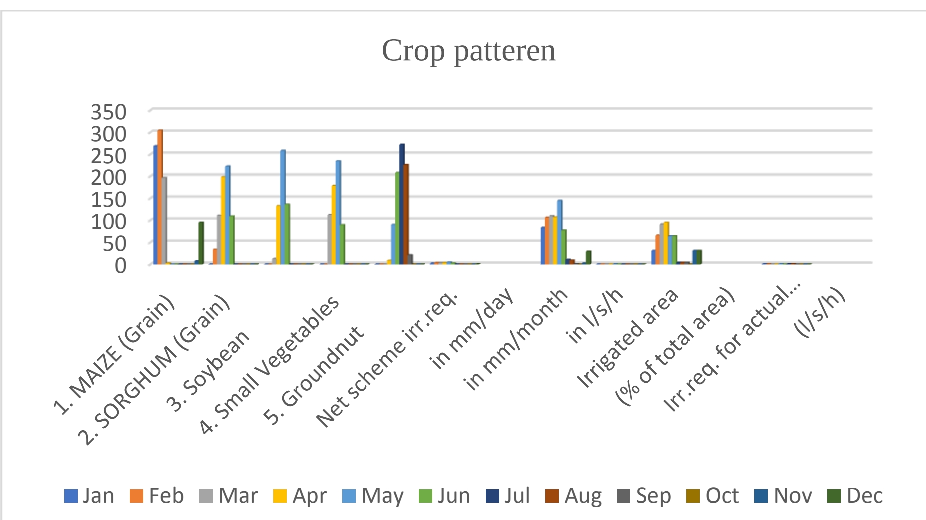


Figure 4.3 crop pattern

4.4. Organizational structure of WUAs

In Rate large-scale irrigation scheme there were five Gotes which were organized for management purposes. There was no clear organizational structure of the water user's association rather they were organized as a water users committee which had eleven members; 9 were males and two of them were females. The WUA committees are male-dominated and the views of women are hardly represented in the decision-making. The structure was as Chairman, Vicechair man, and Secretary. When I was discussing with Woreda experts, they were organized for only water or arranging water distribution period and conflict management. The water committees were not working on their tasks accordingly because they need incentives.

4.4.1. By-laws and fee collection

In Rate large-scale irrigation scheme there were no clear written rules and regulations related to water allocation and distribution. As the Woreda irrigation expert told me, the new working manual was reached to Woreda but was not applicable, they were in the process of training to implement the working manual of the water user's association. The absence of by-laws increases illegal water users and thefts who were taking the gate. Fee collection was not applicable in the irrigation scheme due to these beneficiaries were in problems using the scheme properly because of this the users used the scheme to irrigate two times per year, that is during the rainy season and dry season The maintenance and other costs like fuel for motors are covered by Pastoral office of the project however the role of beneficiaries was participated in clearing only.

4.4.2. Participation of users in operation and maintenance

The irrigation user's participation at the time of the planning and construction period had a positive impact on creating a sense of ownership and sustainability of the irrigation scheme. According to the household field survey users never participated in the planning. The project management was taken responsibility, but they were interested in the diversion site. Beneficiaries did not fully participate in the maintenance of the irrigation scheme, but as Limperier et al. (2004) state, this task was the mandate of WUAs. Irrigation users participated somehow in the cleaning of canals before starting irrigation practice. 68% of irrigation users responded that the maintenance condition of the irrigation scheme was bad as indicated in (Table 4.15.)

Table 4.12 Perception of Users utilisation of irrigation schème

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

4.4.3. Water allocation and distributions

The water allocation and distribution were implemented by the water users committee. The allocation of water was rigid rotational which was fixed time and it was not considered the area size of irrigation beneficiaries. Whatever they have, for all the same amount of water was distributed. The distribution was also never considered the type of crop and their growth stage, for different irrigated crops the same distribution was applied; this led to low production and productivity. As 37.5% of beneficiaries respond, there was a medium distribution of water but some beneficiaries respond that due to head users and illegal water users, unfair distribution was happened (Table 4.13.)

Head and and middle water users were above the control of the water users committee so they did not respect their time of rotation. As a result, tail users were faced water scarcity and irrigated crops were wilted. Therefore, the water users committee should be strengthened to keep their performance.

Table, 4.13. Level of water distribution

Levels	Frequency	Percent
Good	10	31.25
Medium	12	37.5
Bad	6	18.75
Very Bad	4	12.5
Total	32	100

4.4.4. User’s Satisfaction

Manual analysis were done to determine how satisfied users were with the irrigation scheme. Based on data collected during September to December irrigation season, the study's results demonstrate that the probability of users' satisfaction with equity of water distribution is highly significant at 0.1 significance level. Furthermore, the requirements for system operation and maintenance, timely water delivery, and reliable water distribution are significant at 0.5 significance level. Approximately 35.6% of beneficiaries express satisfaction with the irrigation services provided. It was generally found that the irrigation service provided to the user was insufficient, and the program's intended beneficiaries did not receive the benefits. Rearranging WAUs, improving user capacity, and optimizing water delivery scheduling.

5. Conclusion and recommendation

5.1. Conclusion

From this performance evaluation study can conclude that: - The E_c of the scheme was 57.3. %, E_a 63.6%, and overall scheme efficiency was 36.2%. The irrigation ratio of Ratte irrigation scheme was found to be 2.5% which means 97. 5% of the command area was not irrigated during the study period. because more of the users of the scheme are Pastorals. The reason for the low conveyance efficiency in the canal was due to lack of proper maintenance of the watercourses hence it may be evaporation due to the high temperature of the area, seepage and leakage losses, and presence of vegetation and sediments. The loss in conveyance was unavoidable unless the canal was lined or could be minimized with better canal management activities. Therefore, the result shows that too low efficiency of the scheme.

Irrigation water management requires determining when to irrigate and how much water to apply in each application. Knowledge of CWR and soil properties was essential for the management of irrigation water. To enhance the efficiency of irrigation and water management it is highly important to pay special attention to the following: adequate planning and proper design of the irrigation system, maintenance of the conveyance and distribution systems, including regular clearing of weeds growing along the main and secondary canals with full participation of users for the sustainable of using. However, most people in the study area were pastorals, there was a lack of extension work to enhance the users of the irrigation scheme widely.

5.2. Recommendation

Based on the results of the study, the following recommendations are put forward to improve the performance of the scheme;

- In Ratte large-scale irrigation scheme all the primary and secondary canals require lining to increase water conveyance efficiency in the scheme.
- The downstream water users are causes for great water scarcity in this irrigation Therefore, all water users should give equal attention to technical and water management to remove mud,

debris, and vegetation from the banks of the unlined canals to avoid water shortage in the downstream irrigation water user.

- According to the results gained, the water management practice of the scheme was generally poor. Therefore, farmers, development of water management practices, visits to the site for sharing their experience with one another, is an important issue.
- Rehabilitation and reform of the system constructed/operated by the users' association shall be conducted by the person's participation upon their request.
- Regular training on overall irrigation water management, scheme operation, and maintenance should be given to beneficiary farmers.
- Institutional support, continuous monitoring, and evaluation of the scheme are necessary to take immediate corrective action on the problems created by the scheme;
- Empowerment of the water user association is fundamental for irrigation scheme sustainability. Hence, the water user association of the Ratte irrigation scheme has to be further strengthened. Efforts should also be made to bring all beneficiaries of the irrigation scheme under one water user association.

6. Reference

1. Abdul H.Halimi and Ashebir H. Tefera 2019 International Journal of Agriculture & Environmental Science
2. Aklilu, A. (2006). Assessment of irrigation system at Sille state farm, Ethiopia. Master's thesis. Arbaminch University, Ethiopia.
3. Alemayehu, M. (2016). Conveyance and water use efficiency in thirty years old irrigation scheme:establishing baseline information to revitalize the Meki-Ziway irrigation scheme. Master's thesis. Arbaminch University, Ethiopia.
4. Awulachew, S. B., & Ayana, M. (2011). Performance of irrigation: An assessment at different scales in Ethiopia. Experimental Agriculture, 47(S1), 57-69.
5. Bos, M. G., Burton, M. A., & Molden, D. J. (2005). Irrigation and drainage performance assessment: practical guidelines. Cabi Publishing.Clemmens, A. J. (2006)
6. Bos, M. G. (1997). Performance indicators for irrigation and drainage. Irrigation and Drainage Systems, 11(2), 119-137.
7. Bos, M. G., Burton, M. A., & Molden, D. J. (2005). Irrigation and drainage performance assessment: practical guidelines. Cabi Publishing.Clemmens, A. J. (2006).
8. Bos, M.G., Murray-Rust, D.H., Merry, D.J., Johnson, H.G. and Snellen, W.B. (1994). Methodologies for assessing the performance of irrigation and drainage management. Irrigation and Drainage Systems 7: 231-261.
9. C. P. Kumar,2020 Determination of Optimal Cropping Pattern: A Guide for Agricultural Planning.
10. Değirmencİ, H., Büyükcangaz, H., & Kuşcu, H. (2003). Assessment of irrigation schemes with comparative indicators in the Southeastern Anatolia Project. Turkish Journal of Agriculture and Forestry, 27(5), 293-303
11. Dejen, Z. A., et al. (2015). Water Delivery Performance at Metahara Large- Scale Irrigation Scheme, Ethiopia. Irrigation and drainage 64(4): 479-490.
12. Dejen, Z. A., Haileslassie, A., Sally, H., Erkossa, T., Schmitter, P., Langan, S., & Hoekstra, D. (2016). Analysis of water delivery performance of smallholder irrigation schemes in Ethiopia: Diversity and lessons across schemes, typologies, and reaches.

13. Dejen, Z. A., Schultz, B., & Hayde, L. (2012). Comparative irrigation performance assessment in community-managed schemes in Ethiopia. African Journal of Agricultural Research, 7(35), 4956-4970
14. Dejen, Z. A. (2015). Hydraulic and operational performance of irrigation schemes in view of water-saving and sustainability: sugar estates and community-managed schemes In Ethiopia. CRC Press/Balkem
15. FAO (1978). Effective rainfall in Irrigated Agriculture: FAO Irrigation and drainage paper No. 24. Rome, Italy: Food and Agricultural organization of the United Nations.
16. FAO (1986). Irrigation water needs: Irrigation water management training manual no.3. Via dell Terme di Caracalla, 00100 Rome, Italy, international institute for land reclamation and improvement
17. Feyen J, Zerihun D.199 Assessment of the performance of border and furrow irrigation systems and the relationship between performance indicators and system variables. Agric Water Management. 40(2-3):353-362.
18. FWWDSE 2010, Federal water work design supervision enterprise
19. FAO 2017: Water for Sustainable Food Agriculture
20. FAO (1992). Canals, Irrigation Water Management planning, and management: FAO Training Manual No. 7. Rome: Food and Agricultural Organizations of the United Nations.
21. Hailu, H., & Shiberu, E. (2011). Performance Evaluation of Small-scale Irrigation Schemes in Adami Tullu Jido Kombolcha Woreda, Central Rift Valley of Ethiopia (Doctoral dissertation, Haramaya University).
22. John.D.Fenton and Robert Keller September 2001 Technical Report 01/6
23. Keramatzadeh, A., Chizari, A. H., & Moore, R. (2011). Economic optimal allocation of agriculture water: mathematical programming approach. Journal of Agricultural Science and Technology, 13, 477-490.
24. Mahdi Panahi, Khabat Khosravi, December 2021, Journal of Hydrology: Regional Studies, Volume 38
25. Magingxa, L. L., Alemu, Z. G.,& van Schalkwyk, H. D. 2006. Factors influencing the success potential in small holder irrigation projects of South Africa:
26. Malano, H. M., & Burton, M. (2001). Guidelines for benchmarking performance in the irrigation and drainage sector (No. 5). Food & Agriculture Org., P 20

27. Ministry of Water Resources (2002). Water sector development program (2002-2016), irrigation development program. The main report, MoWR, Addis Ababa, Ethiopia: P142
28. M.H.Ali November 2010) Practices of Irrigation & On-farm Water Management: Volume 2
29. Molden, D. J., Sakthivadivel, R., Perry, C. J., & De Fraiture, C. (1998). Indicators for comparing the performance of irrigated agricultural systems (Vol. 20). IWMI
30. Mundial, B. (1999). World Bank atlas from the world development indicators, 1999. In World Bank atlas from the world development indicators, 1999. World Bank.
31. Naeem Shah Bukhari Syed October 2021 Analysis of Conveyance Losses from Tertiary Irrigation Network
32. Ramulu, (1998) Wter conveyance efficiency Small, L. E. & Svendsen, M. (1990). A framework for assessing irrigation performance. Irrigation and drainage systems, 4(4), 283-312.
33. Seleshi Bekele Awulachew July 2010 Irrigation potential in Ethiopia International Water Management Institute
34. Shumye, A.(2017). Evaluation of water delivery performance and irrigation efficiency: A case study of Lemchek–Sewur small-scale irrigation scheme, Amhara, Ethiopia. Masters' thesis. Arba Mich Univesity, Ethiopia.
35. Tariku, E.(2017). Comparative Performances Analysis of Two Small-Scale Irrigation Schemes: Case of Tahtay Tsalit and Mychew, Tigray, Ethiopia Masters' thesis. Arba Mich University, Ethiopia
36. Tahir Saeed Laghari, Abdul Khaliq, December 2014 Analysis of rain fall data to estimate rain contribution towards crop water requirement using CROPWAT model.
37. Wambua, J. M., Makobe, M. N., Njue, E. M., & Nyende, B. A. (2011). Hydroponic screening of Sorghum (Sorghum bicolor L. Moench) cultivars for salinity tolerance. Journal of Agriculture Science and Technology, 12(2).
38. Woodroofe, R. (1993). Monitoring and evaluation of irrigation projects. Technical manual, manual, Ministry of Water, Irrigation and Energy, Addis Ababa, Ethiopia.

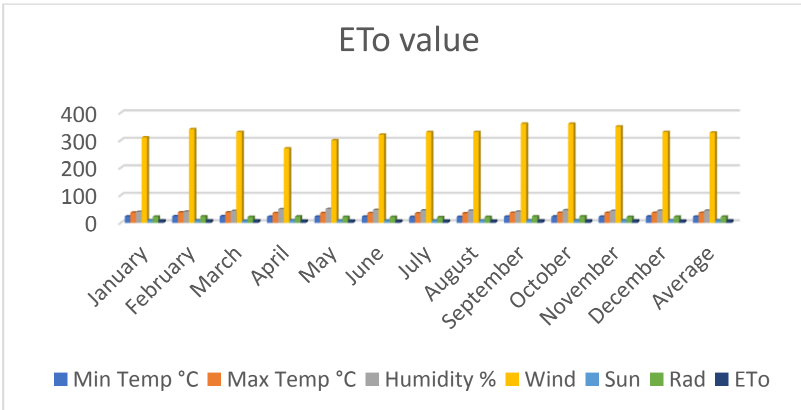
7. Appendices

Table in Appendices (A) infiltration rate measurement using double ring

cumulative time (min)	Infiltration rate (mm/hr)	cumulative infiltration rate (mm/hr)	cumulative infiltration rate (cm/min)
0	0	0	0
2	900	90	1.5
4	720	162	2.7
6	540	216	3.6
8	450	261	4.35
13	396	300.6	5.01
18	288	329.4	5.49
23	216	351	5.85
28	180	369	6.15
38	162	385.2	6.42
48	144	399.6	6.66
58	108	410.4	6.84
68	90	419.4	6.99
88	81	427.8	7.13
108	72	435	7.25
128	68.4	441.6	7.36
148	57.6	447.6	7.46
178	54	453	7.55
208	42	457.2	7.62
238	42	461.4	7.69
268	42	465.6	7.76

Tables In Appendices B: Discharge Measurement

	Time in/sec/	Depth In/ m/	Width In/ m/	Length In /m/	Velocity m/sec	Area in/m^2/	Discharge In m^3/sec	Discharge l/sec
Head	16.5	0.2	0.4	10	0.271	0.08	0.0216	21.6
middle	17.3	0.2	0.4	10	0.294	0.08	0.0235	23.5
tail	17.26	0.2	0.4	10	0.287	0.08	0.0229	22.9
Average					0.284	0.08	0.0226	22.6



Appendices Figure A. of ETo

Table in Appendices C CWR and IR for Maize

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	3	Init	0.3	2.47	9.9	0	9.9
Feb	1	Init	0.3	2.56	25.6	0	25.6
Feb	2	Deve	0.33	2.87	28.7	0	28.7
Feb	3	Deve	0.53	4.56	36.5	0.1	36.4
Mar	1	Deve	0.77	6.51	65.1	4.3	60.8
Mar	2	Deve	1.04	8.66	86.6	6.5	80.1
Mar	3	Mid	1.24	9.83	108.1	6.7	101.4
Apr	1	Mid	1.24	9.35	93.5	7.4	86.1
Apr	2	Mid	1.24	8.85	88.5	8.2	80.4
Apr	3	Mid	1.24	8.87	88.7	6.1	82.6
May	1	Late	1.14	8.17	81.7	3.5	78.1
May	2	Late	0.84	6.03	60.3	1.7	58.7
May	3	Late	0.53	3.83	42.1	1.1	41
Jun	1	Late	0.35	2.56	2.6	0	2.6
Total					817.9	45.6	772.3

Table in Appendices C Schedule for Maize

Date	Day	Stage	Rain Mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
12-Feb	16	Init	0	1	100	57	39.9	0	0	66.5	0.48
1-Mar	33	Dev	0	1	100	59	59.8	0	0	99.6	0.68
14-Mar	46	Dev	0	1	100	59	72.8	0	0	121.3	1.08
25-Mar	57	Mid	0	1	100	60	84.2	0	0	140.3	1.48
4-Apr	67	Mid	0	1	100	56	78.9	0	0	131.4	1.52
15-Apr	78	Mid	0	1	100	58	81.8	0	0	136.3	1.43
26-Apr	89	Mid	0	1	100	58	80.8	0	0	134.6	1.42
8-May	101	End	0	1	100	64	89.2	0	0	148.7	1.43
1-Jun	End	End	0	1	0	74	587.4	0	0	978.7	9.52
							1174.8			1957.4	

Table in Appendices D CWR and IR for Sorghum

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Jan	3	Init	0.3	2.47	9.9	0	9.9
Feb	1	Init	0.3	2.56	25.6	0	25.6
Feb	2	Deve	0.32	2.82	28.2	0	28.2
Feb	3	Deve	0.48	4.14	33.1	0.1	33
Mar	1	Deve	0.67	5.65	56.5	4.3	52.2
Mar	2	Deve	0.88	7.33	73.3	6.5	66.8
Mar	3	Mid	1.03	8.22	90.5	6.7	83.7
Apr	1	Mid	1.04	7.82	78.2	7.4	70.8
Apr	2	Mid	1.04	7.4	74	8.2	65.9
Apr	3	Mid	1.04	7.42	74.2	6.1	68.1
May	1	Late	0.99	7.09	70.9	3.5	67.3
May	2	Late	0.84	6.01	60.1	1.7	58.4
May	3	Late	0.68	4.93	54.2	1.1	53.1
Jun	1	Late	0.59	4.32	4.3	0	4.3
Total					732.9	45.6	687.3

Table in Appendices D Schedule for Sorghum

Date	Day	Stage	Rain Mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
22-Feb	26	Dev	0	1	100	61	69.7	0	0	116.1	0.52
15-Mar	47	Dev	0	1	100	55	94.7	0	0	157.8	0.87
31-Mar	63	Mid	0	1	100	52	102.7	0	0	171.2	1.24
18-Apr	81	Mid	0	1	100	51	100.3	0	0	167.2	1.07
6-May	99	End	0	1	100	56	109.9	0	0	183.2	1.18
1-Jun	End	End	0	1	0	65	477.3	0	0	795.5	4.88
							954.6			1591	

Table in Appendices E CWR and IR for Onion

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Mar	1	Init	0.7	5.9	5.9	0.4	5.9
Mar	2	Init	0.7	5.82	58.2	6.5	51.7
Mar	3	Deve	0.7	5.59	61.5	6.7	54.7
Apr	1	Deve	0.79	5.96	59.6	7.4	52.2
Apr	2	Deve	0.92	6.54	65.4	8.2	57.2
Apr	3	Mid	1.04	7.42	74.2	6.1	68
May	1	Mid	1.07	7.72	77.2	3.5	73.7
May	2	Mid	1.07	7.7	77	1.7	75.4
May	3	Late	1.07	7.75	85.3	1.1	84.1
Jun	1	Late	1.02	7.45	74.5	0.1	74.4
Jun	2	Late	0.98	7.24	14.5	0	14.5
Total					653.2	41.7	611.9

Table in Appendices E Schedule for Onion

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			Mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
11-Mar	2	Init	0	1	100	32	11.7	0	0	19.5	1.13
15-Mar	6	Init	0	1	100	43	17.5	0	0	29.1	0.84
19-Mar	10	Init	0	1	100	39	17.5	0	0	29.1	0.84
22-Mar	13	Init	0	1	100	36	17	0	0	28.3	1.09
25-Mar	16	Init	0	1	100	33	16.8	0	0	27.9	1.08
29-Mar	20	Init	0	1	100	31	16.8	0	0	27.9	0.81
2-Apr	24	Dev	0	1	100	39	23.1	0	0	38.5	1.11
6-Apr	28	Dev	0	1	100	38	23.9	0	0	39.8	1.15
11-Apr	33	Dev	0	1	100	45	30.4	0	0	50.7	1.17
19-Apr	41	Dev	0	1	100	48	36.1	0	0	60.2	0.87
25-Apr	47	Dev	0	1	100	44	35.7	0	0	59.5	1.15
2-May	54	Mid	0	1	100	54	45.1	0	0	75.2	1.24
8-May	60	Mid	0	1	100	48	40.5	0	0	67.5	1.3
14-May	66	Mid	0	1	100	50	42	0	0	70	1.35
20-May	72	Mid	0	1	100	50	41.9	0	0	69.9	1.35
26-May	78	Mid	0	1	100	51	43	0	0	71.7	1.38
31-May	83	End	0	1	100	46	38.8	0	0	64.6	1.5
6-Jun	89	End	0	1	100	50	42.4	0	0	70.6	1.36
12-Jun	End	End	0	1	100	44	540.2	0	0	900	20.72
							1080.4			1800	

Table in Appendices F CWR and IR for Soyabean

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Mar	3	Init	0.4	3.18	12.7	2.4	12.7
Apr	1	Init	0.4	3.01	30.1	7.4	22.7
Apr	2	Deve	0.63	4.51	45.1	8.2	37
Apr	3	Mid	1.1	7.87	78.7	6.1	72.5
May	1	Mid	1.18	8.48	84.8	3.5	81.3
May	2	Mid	1.18	8.46	84.6	1.7	83
May	3	Mid	1.18	8.54	94	1.1	92.9
Jun	1	Late	1.12	8.15	81.5	0.1	81.5
Jun	2	Late	0.73	5.38	53.8	0	53.8
					565.3	30.5	537.2

Table in Appendices F Schedule for Soyabean

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
25-Apr	29	Dev	0	1	100	60	82.2	0	0	137	0.55
8-May	42	Mid	0	1	100	63	87.7	0	0	146.2	1.3
19-May	53	Mid	0	1	100	60	84.6	0	0	141	1.48
30-May	64	Mid	0	1	100	62	87	0	0	145	1.53
16-Jun	81	End	0	1	100	83	116.4	0	0	194	1.32
20-Jun	End	End	0	1	100	12	457.9	0	0	763.2	6.18
							915.8			1526.4	

Table in Appendices G CWR and IR for Ground nut

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Apr	3	Init	0.4	2.85	8.6	1.8	8.6
May	1	Init	0.4	2.87	28.7	3.5	25.2
May	2	Init	0.4	2.87	28.7	1.7	27
May	3	Deve	0.49	3.56	39.1	1.1	38
Jun	1	Deve	0.73	5.3	53	0.1	52.9
Jun	2	Deve	0.95	7	70	0	70
Jun	3	Mid	1.15	8.52	85.2	0	85.2
Jul	1	Mid	1.19	8.8	88	0	88
Jul	2	Mid	1.19	8.83	88.3	0.1	88.3
Jul	3	Mid	1.19	8.89	97.8	1.9	95.8
Aug	1	Mid	1.19	8.94	89.4	4.9	84.5
Aug	2	Late	1.07	8.08	80.8	7	73.8
Aug	3	Late	0.84	6.6	72.6	5.1	67.5
Sep	1	Late	0.67	5.56	22.2	0.9	21.1
Total					852.5	28.1	826

Table in Appendices G Schedule for Ground nut

Date	Day	Stage	Rain Mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
11-May	14	Init	0	1	100	49	28.6	0	0	47.6	0.39
26-May	29	Dev	0	1	100	48	36.5	0	0	60.9	0.47
5-Jun	39	Dev	0	1	100	48	41.9	0	0	69.9	0.81
13-Jun	47	Dev	1.3	1	100	45	43.9	0	0	73.2	1.06
20-Jun	54	Dev	0	1	100	45	47.8	0	0	79.6	1.32
27-Jun	61	Mid	2	1	100	50	55.8	0	0	92.9	1.54
4-Jul	68	Mid	0	1	100	52	58.2	0	0	97	1.6
11-Jul	75	Mid	0	1	100	53	59.1	0	0	98.4	1.63
18-Jul	82	Mid	0	1	100	50	55.9	0	0	93.1	1.54
25-Jul	89	Mid	0	1	100	51	57.6	0	0	96	1.59
1-Aug	96	Mid	0	1	100	52	57.8	0	0	96.3	1.59
9-Aug	104	Mid	0	1	100	52	57.8	0	0	96.4	1.39
18-Aug	113	End	0	1	100	50	56.4	0	0	93.9	1.21
28-Aug	123	End	0	1	100	49	54.9	0	0	91.6	1.06
4-Sep	End	End	0	1	0	28	712.2	0	0	1186.8	17.2
							1424.4			2373.6	

(Appendices figure A) point of infiltration rate

(Appendices figure B) point of infiltration rate

(Appendices figure C) Respondent interview

Appendix (C). Research Questioners

Hawassa University

School of graduate studies

Institute of Technology

Department Bio-System and Environmental Engineering My Name is Bubu Haile from Hawassa University, Ethiopia. I have conducted a study on the performance evaluation on the Rate Large scale irrigation scheme. The main objective of this questionnaire is to recognize the problems with irrigation scheme, with regard to the water delivery system and maintenance issues, which is used for the stockholders to follow appropriate management plans. This is therefore; you are kindly requested to give an answer freely and openly as much as you can. All the questionnaires target in the head, middle, and tail reach of the scheme and collect at household level. The questioner is fully for academic research purposes, any information you give will be kept confidential. Thus, your cooperation is very necessary to achieve the desired goal of the study.

Part 1.

Questioners for individual farmers

1. General

1.1. Research site: ----------------------- region--------------Zone-----------District---------------

PA--------------village---------------

1.2. Interviewer full name----------------------------Date of interview---------------------------------

Time of interview-----------------------------

1.2**.** Household head:

1. Male 2, Female 3. Total

1.3. Age of interviewers

1. 18-20 2. 21-40 3. 41-65 4. >65

1.4. Marital status

1. Married 2. Single 3. Divorce 4. Other

1.5. Educational status of the beneficiaries

1. Reading 2. First cycle 3. Second cycle 4. Illiterate

2. Relevance of the project

2.**1.** What is the main purpose of using irrigation?

1.To generate cash Income

2.To produce food foe the house hold

3. Produce livestock feed

4. Other

2.2. Is your life changed after you start to use this irrigation scheme?

1. Yes 2. No 3. Same as before

2.3. If you say yes, what is/ are the indicators?

1. Income increase 2. Send children to school

2. New house building 4. Other

2.4. What is the source of water for your scheme?

1. River 2. Spring 3. Other

2.5. Are there upstream irrigation water users?

1. Yes 2. No

2..6. Are there downstream irrigation water users?

1. Yes 2. No

2.7. If water is promised on a certain date with a certain flow for a certain Duration, does it arrive that way?

1. Yes 2. No

2.8. Are the canals functional when the farmers need water?

1. Yes 2. No

3. Water distribution system

3.1**.** Have you a specific time for delivering water to each village to address to form blocks?

1. Yes 2. No

3.2. How much time the delivered water take to reach to your command area?

1. 1hrs 2. 2 hrs 3. 3hrs > 3hrs

3.3**.** Is water equally available as full irrigation season in the scheme?

1. Yes 2. No

3.4. If you say No, what are the factors for inadequacy of water in the scheme?

1. Breakage of canals 2. Unauthorized people

3. Water scarcity by upstream users 4. Don’t

3.5. Is the delivered water addresses in all farm blocks?

1. Yes 2. No

3.6. Is water delivery time enough to irrigate crops, according to their needs?

1. Yes 2. No

3.7. Does the water delivery begin at the best date for agronomic purposes?

1. Yes 2. No

3.8. Is there an equitable distribution of irrigation water among all beneficiaries, have you started?

1. Yes 2. No

3.9. What seems like the adequacy of water distribution in the scheme?

1, Good 2. Not good 3. Bad

3.10. What seems like the reliability of water distribution in the scheme?

1. Good. 2. Not good 3. Bad

3,11. How fair is the water distribution among multiple users of the delivery system?

1. Good. 2. Not good 3. Bad

3.12. How do you sense about the water distribution in general?

1. Good. 2. Not good 3. Bad

4. Physical structures and technical aspects

4.1. What seems like physical structures and technical aspects in the irrigation scheme?

1. Good 2. Not good

4.2. Do you see any seepage on the head work, canals and canal structures?

1. Yes 2. No

4.3. Was there any maintenance?

1. Yes 2. No

4.4. What is the community participation by keeping physical structures?

1. Good 2. Not good

4.5. Which system is vulnerable to damage?

1. Head work 2. Main canal 3. Secondary canals

4. Tertiary canals 5. All structures

4.6. Did you experience lack of water due to structure failure?

1. Yes 2. No

4.7. Have you ever taken training on the operation and maintenance of the structures?

1. Yes 2. No

4.8. How do you feel the operation and maintenance work?

1. Satisfied 2. Not satisfied

5. Community participation

5.1. What are the performance management systems seems like according to

1. Water distribution
2. Community participation in meeting
3. Community participation in the financial system
4. Community participation in maintenance

5.2. Do you think the project is important to the community?

1. Yes 2. No

5.3. Do you have rain-fed agriculture in addition to irrigation projects?

1. Yes 2. No

5.4. . If you say yes, how many hectares?

1. < 2 2. >2

5.5. How do you manage your irrigation system?

1. Correct management 2. Incorrect management

5.6. Do you participate in the maintenance of irrigation canals?

1. Yes 2. No

5.7. If you say yes, in what way do you participate?

1. by rule without payment
2. by payment in the form of money
3. by payment in the form of food aid

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

1. Money 2. Labor 3. Material 4. Other

6. Capacity-building problems

6.1. Were capacity building problems in the scheme?

1. Yes 2. No

6.2. What type methods were taken to avoid the problems?

1. Canal cleaning 2. Drainage system 3. Other

6,3, Was there any training given to the beneficiary community before hand over?

1. Yes 2. No

6.4. Is training given after hand over?

1. Yes 2. No

6.5**.** If so, what kind of training?

1. Irrigation agronomy
2. On farm water management
3. Crop diversification

6.6. Who gives the training?

1. Kebele employers 2. Woreda
3. Region 4. Federal

6.7. If the training was taken, for how many days was given by the trainer?

1. < 7 day 2. > 7 days

6.8. Were the community self-readiness to take the training?

1. Yes 2. No

6.9. Do the scheme has been constructed with the permission and full participation of the beneficiaries?

1. Yes 2. No

6.10. Do you irrigate all of your irrigable land?

1. Yes 2. No

6.11. If not, why?

1. Shortage of water
2. Low productivity
3. Poor maintenance

6.12. How many times you produce annually by using irrigation?

1. 1 2. 2 3. > 2

6.13 What are the major agricultural crops you produce using irrigation?

1. Potato 2. Maize 3. Wheat 4. Other

6.14. Type of crops which are produced in the Rate irrigation scheme

1. Horticultural crops 2. Cereal crops 3. Both

6.15. What seems like the crop intensity along the main and secondary canals reach?

1. Decreasing from upstream to downstream   2. Higher at upstream
3. Lower at downstream   4. Equally at all village

6.16. What seems like an annual household income in the scheme?

1. Same as before   2. Higher at upstream
3. Decrease from upstream to downstream   4. Lower at down stream

6.17. What seems like frequency of time missing to get water in command area?

1. 5-7 days   2. 7-10   3 8-11 days
4. 10-14 days   5. 12- 16

6.18, What seems like frequency of time to get water in the villages?

1. Same in all villages   2. Irrigation time decrease in down

6.19. What seems like irrigation methods in the scheme**?**

1. Furrow irrigation   2. Flood irrigation   3. Both

6.20. Generally, how do you feel the irrigation service?

1. Satisfied   2. Not satisfied

Part 2

1. Is there water users' associations (WUAs) and water committee in your scheme?

   Yes [ ]   No [ ]

2. If your answer is yes what looks like the strength of the WUAs and water a committee in managing the scheme?

   [ ] Strong   [ ] Medium   [ ] Weak

3. If the management is weak, what are the major management problems related to water distribution in the irrigation system?

   [ ] Sanction not imposed against illegal water users' [ ] Poor coordination of water distribution by WUAs of a water committee

   [ ] Rotation does not accomplish equality [ ] Rotation is not strictly implemented

4. Is there any established bylaw in Rate irrigation scheme?

   [ ] Yes   [ ] No

5. Is there any fee that could be collected from the irrigation users?

   [ ] Yes   [ ] No

6. Who is the responsible body for the operation and maintenance of the scheme?

   [ ] Farmers   [ ] government   [ ] water committee

7. What is your landholding size ________________________________?

8. Location of your farm plot from canal head [ ] near [ ] far

9. Is the available irrigation water adequate for your farmland?

[ ] Yes [ ] No

10. If not, what are the possible reasons for inadequate water supply of the canals?

[ ] Poor scheduling of available water supply [ ] sedimentation problem

[ ] Over-abstraction by upstream water user [ ] poor control by O&M staff

[ ] poor motivated O&M staff [ ] Inadequate supply of water source

[ ] Damaged control structures (at intake**)** [ ] Inadequate canal capacity

[ ] Other

11. In general what do you feel about the adequacy of irrigation water in the scheme?

[ ] Satisfied [ ] dissatisfied

12. Does the supplied water reliable and delivered at the scheduled time

[ ] Yes [ ] N0

13. If no, what are the possible reasons [ ] water scarcity

[ ] unequal water distribution [ ] unfortunate Irrigation scheduling

[ ] over-abstraction of water by upstream users [ ] others

14. What do you feel about the reliability of Rate irrigation scheme?

[ ] Satisfied not satisfied [ ]

15. Is there equitable distribution of irrigation water among all beneficiaries?

16**.** If no, what are the causes for the unequal water distribution?

[ ] water scarcity [ ] unequal water distribution [ ] unfortunate Irrigation scheduling

[ ] over-abstraction of water by upstream users [ ] other

17. How do you feel about the water distribution in general?

[ ] Satisfied [ ] Not satisfied

18. Generally, are you satisfied with the irrigation service received

[ ] yes [ ] No