



**PERFORMANCE EVALUATION OF CHANCHO SMALL SCALE
IRRIGATION SCHEME IN LOKA ABAYA WOREDA, SIDAMA
REGIONAL STATE, ETHIOPIA**

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HAWASSA UNIVERSITY
INSTITUTE OF TECHNOLOGY SCHOOL OF GRADUATE
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REGIONAL STATE, ETHIOPIA

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DEDICATION

I dedicate this thesis manuscript to my beloved friends and all my families for their love and their moral support during my studies.

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ABBREVIATION AND ACRONYMS

BD	Bulk density
CWR	Crop water requirement
DPR	Deep percolation ratio
Du	Distribution uniformity
Ea	Application efficiency
Ec	Conveyance efficiency
EI	Irrigation efficiency
EO	Overall scheme efficiency
EPCC	Ethiopia panel on climate change
Es	Water storage efficiency
ETC	Crop evapo-transpiration
ETO	Reference crop evapo-transpiration
FAO	Food and agricultural Organization
FC	Field capacity
GPS	Global positioning system
IFAD	International fund for agricultural development
KC	Crop coefficient
M.a.s.l	Meter above sea level

MOA	Ministry of agriculture
MOWR	Ministry of water resource
NGOS	Non-governmental organization
PWP	Permanent wilting point
Q	Discharge
RAW	Readily available water
RR	Run off ratio
SIE	Scheme irrigation efficiency
SSIP	Small scale irrigation project
SWWA	South water work agency
TAW	Total available water
USBR	United State Bureau of Reclamation
USDA	United State Department of Agriculture

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ABSTRACT

Performance evaluation of irrigation schemes helps to know the present status of the scheme and enables to employ possible measures for improvement. Efficient operation and management for irrigation system plays an important role in the sustainability of irrigated agriculture. This study was initiated to evaluate the performance of Chancho small-scale irrigation scheme using internal performance indicators. Primary data collected for this study include field discharge measurement and determination of soil physical properties in laboratory. Secondary data were collected from different sources. Internal performance indicators used in this study were efficiency parameters (conveyance, application, and storage), distribution uniformity, deep percolation loss, depth of irrigation and irrigation interval. The result of study showed that average conveyance efficiency MC and SC-1 and SC-2 were 64.68, 64.1 and 65.4% respectively. Water distribution uniformity at the head, middle, and tail of the field were 72.6, 66.6, and 75.2% respectively. Application efficiency of head, middle and tail end of selected field were 49.3, 51.4 and 68.7% respectively. Water storage efficiencies of head, middle and tail end of selected fields were 83.4, 80.2 and 87.7% respectively. The result of the study showed that average over all conveyance efficiency, average application efficiency, scheme storage efficiency and average deep percolation loss were 65.1, 56.5, 83.7 and 43.5% respectively. The result of the study also showed that farmer's application depth of irrigation water was lower than depth of irrigation water that would be required to fill root zone to field capacity. As result showed calculated irrigation intervals was greater than farmer adopted. The study showed that over all irrigation efficiency was relatively poor. Generally, overall performance of the scheme is considered as low. So it is important to adopt water management practices, frequent training of irrigation water user farmers and maintenance canal water conveyance system to achieve good performance of the scheme.

Key words: *Chancho small scale irrigation, Performance evaluation, internal indicators, irrigation efficiency*

1. INTRODUCTION

1.1. Background of the Study

Ethiopia is one of few African countries endowed with abundant water resources. The country has 12 river basins with an annual runoff volume of 124 billion cubic meter of water and an estimated ranges of 2.6 billion cubic meter to 30 billion cubic meter ground water potential (EPCC, 2015). Ethiopia is rich with extensive land areas suitable for irrigation. According to, Awulachew (2010) Ethiopia comprises 112 million hectares (Mha) of land. Cultivable land area estimates vary between 30 to 70 Mha.

The irrigation potential is also estimated about 5.3 million ha from 15 million ha of total cultivated area. The irrigation area of the country is 640,000 ha. Of these 120,000 ha using rain water harvesting, 383,000 ha from small scale irrigation and 129,000 ha from medium and large scale irrigation systems (Awulachew et al., 2010).

Irrigation is extremely predictable to play a major role in the realization of Ethiopian food security and poverty alleviation strategy. Irrigation enhances agricultural production and improves the food supply, income of rural population, opening employment opportunities for the poor, supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops. One of the best alternatives to consider for reliable and sustainable food security development is expanding of small scale irrigation development in the country (Awulachew et al., 2008).

Small scale irrigation structures, owing to their relatively small investment cost, ease of construction, simplicity of operation & maintenance has been a strategic target of the country for achieving sustainable food security and self-sufficiency (Lambisso, 2008).

The vital role of irrigated agriculture within the context of poverty reduction, efforts of the country is well understood as it increases the production of agricultural raw materials, exploit land and water asset with enhanced sustainability, reduce dependency on rain-fed agriculture and its vulnerability to erratic rainfall prevailing in the country and avoid the shattering consequences of periodic drought (MoWR, 2002).

To achieve sustainable production from irrigated agriculture it is obvious that the utilization of the important resources in irrigated agriculture; water and land must be improved. Thus on-farm irrigation systems and operations need to be evaluated against the potential efficiency of the systems. Performance assessment has been an integral part of irrigation since man first started harnessing water to improve crop production. Evaluation involves measuring conditions at one or more points in a field selected to be typical or representative for the irrigation projects (Pereira and Trout, 1999).

Performance evaluation is major component of proper irrigation water management; the most common problem in performance evaluation of irrigation scheme is lack or non-reliability of data. In most cases people believe that irrigation scheme with modern system will have high performance, but use of modern method of field application alone doesn't guarantee high performance. The major reason for the low performance of irrigation systems is inaccurate water distribution due to the lack of a monitoring system for water delivery (Lozano and Mateo's, 2008).

Poor distribution and management of water in irrigation systems is a major factor leading to low efficiency, and thus, there is a need to assess the extent to which present irrigation systems in the area achieve their distribution aims (Yercan et al., 2009).

International Water Management Institute developed two types of indicators to evaluate irrigation systems: internal and external indicators. This study focused only internal performance indicators. According to Kloezen et al., (1998) the aim of applying internal indicators is used to assess actual irrigation performance relative to system specific management goals and operational target.

1.2. Statement of the problem

Irrigation is major significance in many countries of the world. It is significant in terms of agricultural production and food security, enhancing the income of rural people and public investment for rural development. However there is wide spread dissatisfaction with the performance of irrigation projects in developing countries (Behailu et al., 2004).

The issue of food security is exacerbated by the rapid growth of population and hence of the demand for food. Poor management of available water for irrigation, both at system and farm

level has led to a range of issues and further aggravated water availability and has reduced the benefits of irrigation investments (FAO, 1996).

Assessment of irrigation performances is very essential to know the system operation levels and checking out management activities of irrigation schemes. However, in Ethiopia, especially in Sidama region, performance evaluation of irrigation schemes is rarely conducted. The interventions so far made by Federal and regional government and NGO's in Sidama region focuses on the development of new irrigation schemes and upgrading the physical infrastructures of existing traditional irrigation schemes (Awulachew et al., 2007).

In Sidama region Chanco small scale irrigation scheme was built and rehabilitated. However, issues such as, water use rights and allocation, operation and maintenance, and establishment and strengthening of evaluation of the performance is also should be the most essential part of project management. Poor system management, poor understanding of farmers' priorities, lack of clear and sustainable water share among users, conflict of water users, low level of ownership of the scheme, due to lack of awareness and frequent training for water delivery and management, canals were filled with sediment and other materials before irrigation season started. Farmers spent their time in cleaning canals every season before irrigation started, the water control structures constructed in the scheme were not operational and high amount water losses in the conveyance system were the major factors.

The evaluation of existing irrigation schemes is relevant for improving its performance and increasing the productivity. Despite the poor performance of the irrigation schemes in the Country, evaluation of small scale irrigation schemes and benchmarking of the results is not common; this is particularly true in using the internal performance indicators. Therefore, this study was aim to evaluate the performance level of Chanco small-scale irrigation scheme using internal performance indicators for better water management that can also be used as a point of entry for better irrigation water management options.

1.3. Objectives of the Study

1.3.1. General Objective

The overall objective of this study is to evaluate the performance of Chanco small-scale irrigation scheme by using internal performance indicators.

1.3.2. Specific Objectives

- ✓ To assess the current performance of Chanco small scale irrigation schemes by using performance indicators. Namely conveyance efficiency, application efficiency, storage efficiency, distribution uniformity and deep percolation.
- ✓ To evaluate irrigation practices of farmers in the scheme.

1.4. Research Questions

- ✓ What are the current performance levels of the scheme?
- ✓ What are the irrigation practices in Chanco small scale irrigation scheme?

1.5. Significance of the Study

The results of this study would provide information for the performance or productivity of the current irrigation scheme. Irrigation projects have the potential to degrade the land, the soil and waste the valuable resource water, if they are mismanaged. In recognition of both the benefit , assessment and evaluation of irrigation scheme, performance has now become a paramount importance not only to point out where the problem lies but also helps to identify alternatives that might be both effective and feasible in improving system performance.

1.6. Scope of the Study

The study was intended to evaluate the performance of Chanco small-scale irrigation scheme by focusing on; internal performance indicators of irrigation scheme. The study, finally makes a critical analysis of the issues related to irrigation system performance, and recommends the remedial measures to improve the performance. The study covered from the diversion point (weir) up to the end of the irrigation system layout.

2. LITERATURE REVIEW

2.1. Overview of Irrigation Development in Ethiopia

Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops in Awash Valley. The need of developing irrigation for crop production is acquiring more and more attention in Ethiopia in response to the growing demand for agricultural crop. In general, Ethiopia receives an annual rainfall apparently adequate for food crop and pasture production. Modern small-scale irrigation (SSI) development and management started in the 1970s initiated by the Ministry of Agriculture (MoA) in response to major droughts, which caused wide spread crop failures and food insecurity (Teshome, 2006).

Ethiopia covers a land area of 1.13 million km^2 , of which 99.3 percent is a land area and the remaining 0.7 percent is covered with water bodies (MoWR 2002). It has an arable land area of 10.01 percent and permanent crops covered 0.65 percent while others covered 89.34 percent.

According to Ethiopian irrigation scheme classification, small-scale irrigation scheme (SSI) is defined as the area less than 200 ha; which are often community-based and traditional methods. The traditional small scale irrigation uses simple water diversions. It has been practical for decades in the high land where small farms could divert river, spring water seasonally for a limited dry season cropping (Awulachew et al., 2005).

2.2. Importance of Irrigation Development in Ethiopia

Irrigation in Ethiopia is considered as a basic strategy to alleviate poverty and hence food security (Belete, 2006). It is useful to transform the rain-fed agricultural system which depends on rainfall into the combined rain-fed and irrigation agricultural system. This is believed to be the most prominent way of sustainable development in the country. However, the development of irrigation practices in Ethiopia has to be investigated so as to seriously know the history of irrigation emergence and its subsequent developments (Haile and Kasa, 2015; Hagos et al., 2009).

Irrigation advancement is vital to the sustainable and reliable agricultural developments in Ethiopia. Subsistence dominated smallholder farmers' economy can be improved through the use of irrigation in the Ethiopian agriculture (MoA, 2011).

According to Hagos et al., (2009) were noticed that irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia. A study also indicated that one of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales, through river diversion, constructing micro dams, water harvesting structures, etc.

2.3. Irrigation Water control and Management

According to Salman et al., (2012) "Water management" is defined as the planned development, distribution, and use of irrigation water in accordance with predetermined objectives and with respect to both quantity and quality of the water resources. Water management is a prime factor in the success of an irrigation system. Large quantities of water, and often large labor inputs, are required for irrigation. The irrigator can realize profits from investments in irrigation equipment only if water is used efficiently. Every planning activity that has something to do with water can be looked upon as water management in the broadest sense of the term.

According to United States Bureau of Reclamation (2005), Irrigation water management is the act of timing and regulating irrigation water applications in a way that will satisfy the water requirement of the crop without the waste of water, soil, plant nutrients, or energy. The on-farm irrigation water need to be measured to determine the potential efficiency of the systems as designed and the actual efficiency that is obtained with present management (Merriam et al., 1983). There is no way that the cultivated area without a water management system can contribute significantly to the required increase in food production (Schultz and De Wrachien, 2002).

2.3.1. Regulation of flow discharge and water level

Irrigation scheme flows are managed with the help of hydraulic structures and water reaches the fields at the given time and in the quantities needed. To transport water from the source (often at some distance from the cultivated fields) to the fields, an infrastructures consisting of canals and regulation structures are necessary. An organizational structure is needed to execute the necessary tasks to manage and control the infrastructures (Ertsen, 2005).

According to Kraatz and Mahajan (1975) water level and velocity control structures comprise a group of engineering works installed in open canal irrigation networks designed to regulate the

water level in a canal, to control the quantity of water passing through it, to dissipate energy and enable water to be delivered accurately and safely to the fields without causing erosion. Such structures include checks or cross-regulators, drops (or falls) and chutes.

Water control refers to the ability of the system to distribute, apply or remove water at the right time, in the right quantity and at the right place. The main objectives of water control in an irrigation project are to deliver reliability (temporal), adequacy (volume balance, including seepage, operational and application losses) and equitable water to irrigation fields (spatial parameters) (Lowdermilk, 1981). In view of its aim, an irrigation system has to be planned, constructed, operated and managed in such a way that all of the farm fields in the command area will receive and discharge water in an appropriate, conveniently arranged and adjustable manner (Depeweg, 1999).

The measurement of irrigation water is an essential element for its fair distribution and economical use. Measurement serves to ensure the maintenance of proper delivery schedules and to determine the amounts of water delivered.

According to Ertsen (2005) by means of weirs, dams, canals and other constructions, the spatial and temporal distribution of water is regulated. The collection, control, allocation and distribution of water to groups of fields and producers are the core processes of an irrigation system. Irrigation systems collect; transport and distribute water for agricultural production with the goal to supply the root zones of the cultivated crops with the necessary amount of water.

2.3.2. Irrigation water management

The management of irrigation systems aims to achieve optimal crop production and efficient water use or in other term a reliable, predictable and equitable irrigation water supply to farmers. Inequity of water distribution occurs very often. Farmers are not sure when and how much water they can expect, which leads to very little cooperation and involvement in irrigation management and limited contribution to operation and maintenance costs (Wil and Vander, 1994).

Playan and Mateos (2004) defined that the function of the conveyance and distribution systems and services should provide sufficient water in a timely manner so that it can be used efficiently for crop production. Reliability and efficiency are then keywords for a modernization plan. The reliability of an irrigation service is the degree to which the irrigation system and its

water deliveries conform to the expectations of the users. A reliable service allows efficient irrigation management within the constraints of the system.

The ever-increasing water demand compared with the depleting water resources warrants refined water use practices in irrigated agriculture to attain improved socio-economic benefits. In the past years the improvement in the irrigation system concentrated in the hardware component namely the physical aspects like structures but limited on the software part namely water usage for agricultural purpose. A good management, proper and timely application of water may result in better yield and reduction in drainage problems (Vidhya et al., 2002).

The responsibility for the management of the on-farm water distribution and the water application belongs to an individual farmer. The management is responsible for the operation and maintenance of the irrigation and drainage system (Depeweg, 1999).

2.4. Performance Assessment of irrigation systems

Performance assessment of irrigation can be defined as the systematic observation, documentation and interpretation of activities related to irrigated agriculture with the objective of continuous improvement (Molden et al., 2007).

Population increase and the improvement of living standards brought about by development will result in a sharp increase in food demand during the next decades. Several studies show that the contribution of expanding agricultural land for the required increase in production is relatively low; and the contribution of cultivated lands, particularly that of irrigated lands will be much higher. Although there are various views on the speed of the required increase in agricultural production, the major part of the increase (80-90%) would by and large have to come from already cultivated lands; among other means, by improved irrigation practices, increased intensity, improved drainage practices, and increase in storage.

2.4.1. Need for Performance Assessment

Performance assessment for any irrigation system is essential to assess how far the goals and objectives set forth at the time of project formulation of the system have been achieved. This is a useful tool to provide necessary feedback for improving the systems management by initiating remedial measures (Raghava et al., 2011). Performance assessment is a basic portion of

administration. It is needed to target and monitor actual achievements in operation and take appropriate actions if required.

According to Molden (1998), Performance is assessed for a variety of reasons: to assess progress against strategic goals, to assess the general health of a system, to improve system operations, as an integral part of performance oriented management, to assess impacts of interventions, to better understand determinants of performance, and to compare the performance of a system with others or with the same system over time.

According to Bos et al., (2005), describes the purpose of performance assessment is to achieve efficient and effective irrigation performance by providing related feedback to management at all levels. Efficient operation and management for small scale irrigation system plays an important role in the sustainability of irrigated agriculture. Hence, irrigation project performance studies are being used with increasing frequency to encourage this objective.

The main purpose for performance assessments are to evaluate the general condition of the system regarding to water delivery and improve system operation. More importantly, if an irrigation system committed to the farmers satisfaction, it can supply more and better sustainability information.

Arunkumar and Ambujam (2010), discussed that the ultimate purpose of performance assessment is to achieve an efficient and effective use of water resources.

2.5. Crop Water Requirement and Irrigation Water requirement

Crop water requirements (CWR) encompass total amount of water used in evapotranspiration. (SAVVA and FRENKEN, 2002) defined crop water requirements as „the depth of water needed to meet the water loss through evapotranspiration of a crop and achieving full production potential under the given growing environment“. Crops will transpire water at the maximum rate when the soil water is at field capacity. Adequate data on irrigation water requirements of most crops is not available in developing nations of the world. This is one of the reasons why for the failure of large scale irrigation projects in most developing countries of the world (Adeniran et al., 2010).

Irrigation requirements (IR) refers to water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirements. The accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapotranspiration (Nuha and Henery, 2000).

2.6. Reference Crop Evapotranspiration

The evapotranspiration from a reference surface not short of water is called the reference crop Evapotranspiration and is denoted by ET_o . Relating evapotranspiration to a specific surface provides a reference to which evapotranspiration from other surfaces can be related.

recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the FAO Penman Monteith equation has been adopted as the globally best performing method of estimating reference crop evapotranspiration based on the inputs geographical coordinates (latitude, longitude and elevation) of the nearby meteorological station, monthly climatic data (minimum and maximum temperature, relative humidity, sunshine duration and wind speed). ETO for each month was calculated for a 'decade' (every ten days) (Supe et al., 2015).

2.7. Irrigation Scheduling

Irrigation scheduling is the practice when to start an irrigation system and how much water to apply. No matter what method is used, they all start with knowing when and how much rain has been received on the field and then using some mechanism to decide when to irrigate (Thomas et al., 1999).

Irrigation scheduling is the utilizing of water administration strategies to prevent over application of water while minimizing yield loss due to water shortage or drought stress. The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation. Irrigation scheduling is important for irrigator to apply the exact amount of water to achieve the goal that increases irrigation efficiency (El Afandi et al., 2010; SAVVA and FRENKEN, 2002).

Irrigation scheduling is the process of deciding when to irrigate and how much water to apply per irrigation. Among the benefits of proper irrigation scheduling is: improved crop yield and/or quality, water and energy conservation, and lower production costs (Rijo and Pereira, 1987). Irrigation scheduling is an important irrigation management issues for maximizing production efficiency.

2.8. The FAO CROPWAT 8.0 model

CROPWAT is a computer program that can calculate crop water and irrigation requirements from climatic and crop data. The program is interactive in nature. In addition to this, the program allows the development of irrigation schedules for different management conditions and the estimation of scheme water supply for varying cropping patterns. The CROPWAT model is based on a water balance model where the soil moisture status is determined on a daily basis from calculated evapotranspiration and inputs of rainfall and irrigation. The versions of CROPWAT 8.0 have been released. The program uses monthly climatic data (temperature, relative humidity, wind speed, sunshine hours, and rainfall) for the calculation of reference evapotranspiration (Clarke et al., 2001).

Its newest version, CROPWAT 8.0 has been developed by Joss Swennenhuis for the Water Resources, Development and Management Service of FAO (Mehanuddin, 2018). Methodologies for crop water requirements and yield response to water are used, while the actual evapotranspiration is determined from the soil moisture status (SAVVA and FRENKEN, 2002).

2.9. Irrigation efficiency

According to Michael (1997), irrigation water use efficiency is the ratio between the volume used by plants through evapotranspiration process and the volume that reaches the irrigation plots and indicates how efficiently the available water supply is being used, based on different methods of evaluation. The design of the irrigation scheme, the degree of land preparation, and the skill and care of the irrigators are the principal factors influencing irrigation efficiency.

According to Eticha (2011), irrigation efficiencies are evaluated at scheme or on-farm level for the purpose of identifying 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, to determine the overall irrigation efficiency. The most common way to express the efficiency of irrigation systems is to subdivide it into conveyance and application efficiencies. Identifying the various components and knowing what improvements can be made is essential to making the most effective use of this scarce resource.

According to FAO (1989), a scheme irrigation efficiency of 50–60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20–30% is considered to be poor. It should be kept in mind that the values mentioned above are only indicative values. The performance of farm

irrigation is determined by the efficiency with which water is diverted, conveyed, and applied; and by the adequacy and uniformity of application in each field on the farm. Among the factors used to judge the performance of an irrigation system or its management, the most common ones are efficiency and uniformity.

2.10. Performance Evaluation of irrigation schemes

Evaluation is information processing to examine goals and strategies, to compare the results of monitoring and observations with the present standards or targets and asks whether the strategic plan is on track (Malano and Burton, 2001). It takes into account the accuracy of planning assumptions and the effectiveness of planning strategies. Performance evaluation is a major activity of appropriate administration, which in turn is the basis for optimal use of land and water assets. The evaluation of surface irrigation at field level is an important aspect of both management and design of the system. Field measurements are necessary to characterize the irrigation system in terms of its most important parameters, to identify problems in its function, and to develop alternative means for improving the system.

The type of performance measures chosen depends on the purpose of the performance assessment activity (Molden et al., 1998). With these types of indicators the amount of deviation between the actual values against the intended are evaluated. Better management is dependent upon appropriate methods and measures by which system performance can be evaluated relative to the management objectives.

Hence, reliable measures of system performance are extremely important for improving irrigation policy making and management decisions. The development potential for small- scale irrigation seems attractive in view of cost effectiveness, well-focused target group and its sustainability through empowerment of the beneficiaries. However, experience has shown that there are still considerable constraints and setbacks that hinder the introduction of small- scale irrigation. Regarding the different approaches of soliciting evaluation data, it can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year. The other means of collecting the evaluation data is through conducting assessment research.

2.10.1. Irrigation performance indicators

Performance indicators measure the value of a particular item such as yield or canal discharge and have to include a measure of quality as well as quantity and be accompanied by appropriate standards or permissible tolerances. Performance indicators reflect the level of adequacy in the use of resources to obtain the final outputs in irrigation schemes (Bos et al., 2005).

Indicators are a way of measuring progress towards the achievement of the goal, i.e. the targets or standards to be met at each stage. They provide an objective basis for monitoring progress and evaluation of final achievements (Savva and Frenken, 2002).

Bos (2007) summarizes the performance indicators currently used in the Research Program on Irrigation Performance. Within this program field data are measured and collected to quantify and test multidisciplinary performance indicators. These indicators cover water delivery, water use efficiency, maintenance and sustainability of irrigation, environmental aspects, socio-economic and management. He also noted that it is not recommended to use all described indicators under all circumstances.

2.10.2. Internal performance indicators

These indicators examine the technical or field performance of a project by measuring how close an irrigation event is to an ideal one. An ideal or reference irrigation is one that can apply the right amount of water over the entire region of interest (i.e. depth of root zone) uniformly and without losses (Feyen and Dawit, 1999). 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. Internal indicators examine the mechanisms of water control and allocation at all levels of the project and provide systematic rating of hardware, management and service throughout the entire system Kuscu et al., (2009).

As Burt (2002), states 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.

A) Conveyance efficiency (E_c)

Conveyance efficiency is defined as the ratio of the amount of water that reaches the Field to the total amount of water diverted into the irrigation system. Losses of irrigation water in the conveyance system can be a major component of the overall water losses particularly for farms

located at significant distances from water sources where the main canals are long and unlined. The amount lost depends on quality of operation, maintenance and the nature of the soil that affects the seepage rate. It represents the efficiency of water transport in canals.

As Howell,(2003) explained that the conveyance efficiency is typically defined as the ratio between the water that reaches a farm or field and that diverted from the irrigation water source. According to Hansen et al., (1980), the earliest irrigation efficiency concept for evaluating water losses was water-conveyance efficiency. Most irrigation water then came from diversions from streams or reservoirs. Losses which occurred while conveying water were often excessive. The concept can also be viewed as the evaluation of the water balance of the main, lateral and sub-lateral canals and related structures of the irrigation system (Bos et al., 1993). It is one of the several closely related and commonly used output measures of performance that focus on the physical efficiency of water conveyance by the irrigation system.

Losses of irrigation water occur during the transit from the head of a canal up to the farm plot. Conveyance efficiency is mainly depends on the length of the canals, the soil type, permeability of the canal banks and the condition of the canals. In large irrigation schemes, more water is lost than in small schemes due to a longer canal system.

B) Application efficiency (E_a)

Application efficiency relates to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field. When Water is diverted into any water application system such as furrows, part of the water infiltrates into the soil for consumptive use by the crop, while the rest is lost as deep percolation and as Runoff.

Water application efficiency gives a general sign of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. The objective is to apply the water and to store it in the crop root zone to meet the crop water requirement (Odhiambo and Kranz, 2011). After the water reaches the field supply channel, it is significant to apply the water as efficiently as possible. A measure of how efficiently this is done is the application efficiency.

According to Kenneth (1988), indicated that attainable water application efficiencies vary greatly with irrigation system, type and management. Depending on the type of the source, water is diverted, or pumped to a canal or pipe for Conveyance to the farm for distribution and finally for application to the crops in the field. The determination of the water application efficiency by soil

moisture measurements requires two components of water balance, i.e. depth of water applied, depth of water stored in the root zone plus beneficially used depth of water. But the irrigation system in the study project is operated primarily to supply water for crop ET, which allows water application efficiency (E_a) and irrigation efficiency (E_i) to be used interchangeably. The measurement of depth of irrigation water delivered to individual farm or plot for a particular irrigation can be made by measuring flow of irrigation stream and time for which water is applied and divided by the plot area. The stored depth is measured in terms of soil moisture status and can either be measured by taking soil samples before and after irrigation. This is the goal of efficient irrigation to ensure the greatest amount of water that is delivered to the farm is used by the crop rather than being lost to groundwater or off the farm as drainage.

According to Berhanie Endrie (2017), the attainable water application efficiency of furrow irrigation system ranges from 60 - 80 % and efficiency of surge flow irrigation system ranges from 65 up to 80 %. According to Lema Teklu (2016), evaluation of the performance of surface irrigation methods at MelkaWerer, Middle Awash Valley, indicated that the maximum possible application efficiency for furrow irrigation computed was 64.5%.

C) Water storage efficiency (E_s)

Storage efficiency is an index used to measure irrigation adequacy. It is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root zone. Conceptually, the adequacy of irrigation depends on how much water is stored within the crop root zone, losses percolating below the root zone, losses occurring as surface runoff or tail water the uniformity of the applied water, and the remaining deficit or under irrigation within the soil profile following irrigation. The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation.

As Zerihun et al., (1997), also defined storage efficiency as a ratio of the volume of water actually stored in the subject region to the volume of water that can be stored. Small irrigations may lead to high application efficiency, yet the irrigation practice may be poor. The concept of water storage efficiency is useful in evaluating this problem.

D) Distribution uniformity (Du)

Irrigation systems are not capable of applying exactly the same depth of water to every location in the field. Thus, non-uniform applications lead to non-uniform depths of infiltration and ultimately to varying amounts of soil water in the root zone. Non-uniform application leads to more deep percolation which results in lower application efficiencies and sometimes to chemical leaching (Irmak, S., 2011). Distribution uniformity is a measure of how uniformly water is applied during an irrigation event. The uniformity of application can have a considerable effect on crop yield and optimum water application. The goal of every irrigator should be to apply the right amount of water as uniformly as possible to meet the crop needs. To do the job right, irrigators need to take in to account how much water is applied during irrigation and where the water goes (uniformly).

According to (FAO, 1989 and Roger et al., 1997) explained that water lost to percolation below the root zone due to non-uniform application or over-application water runoff from the field all reduces irrigation efficiencies.

E) Deep percolation ratio (DPR)

A component of the irrigation applied to a field percolates into the soil below the root zone.

The loss of water through drainage beyond the root zone is reflected in the deep percolation ratio. DPR expresses the ratio between the percolated water beyond the root zone to the volume of water applied to the field (Feyen and Dawit, 1999).

3. MATERIALS AND METHODS

3.1 Location and Description of the Study Area

3.1.1. Location of the study area

Chancho small scale irrigation project is located in Sidama Region Loka abaya Woreda, Dese kebele. The command area is bounded by Mete and Chancho rivers in the north east and south. In the west a gravel road from Aposto town to Chalbesa Keble delineates and divides the Command area as the main accesses road having 19km of distance. The project area is situated within rift valley basin. The weir site GPS reading is 422635m Northing, 742414m Easting and 1684 m.a.s.l elevation. The site is accessible via Loka abaya to Kege kebele all-weather road. Total distance of the headwork site is 54km and 10km from Hawassa Town and Hantate (Woreda Capital) respectively. Chancho SSIP is a river diversion irrigation project studied and designed and rehabilitation work done by SNNPRS Bureau of Water & Irrigation; International fund for agricultural development (IFAD) and South water work agency (SWWA) in 2008. The topography of the command area is described as flat to gently sloping plain. The source of water for this project was Gidawo and Chancho River. The all portion of the main canal as well as secondary canals are masonry rectangular canal. The design document reveals the irrigable land area 130 ha. (*Source: Design document*).

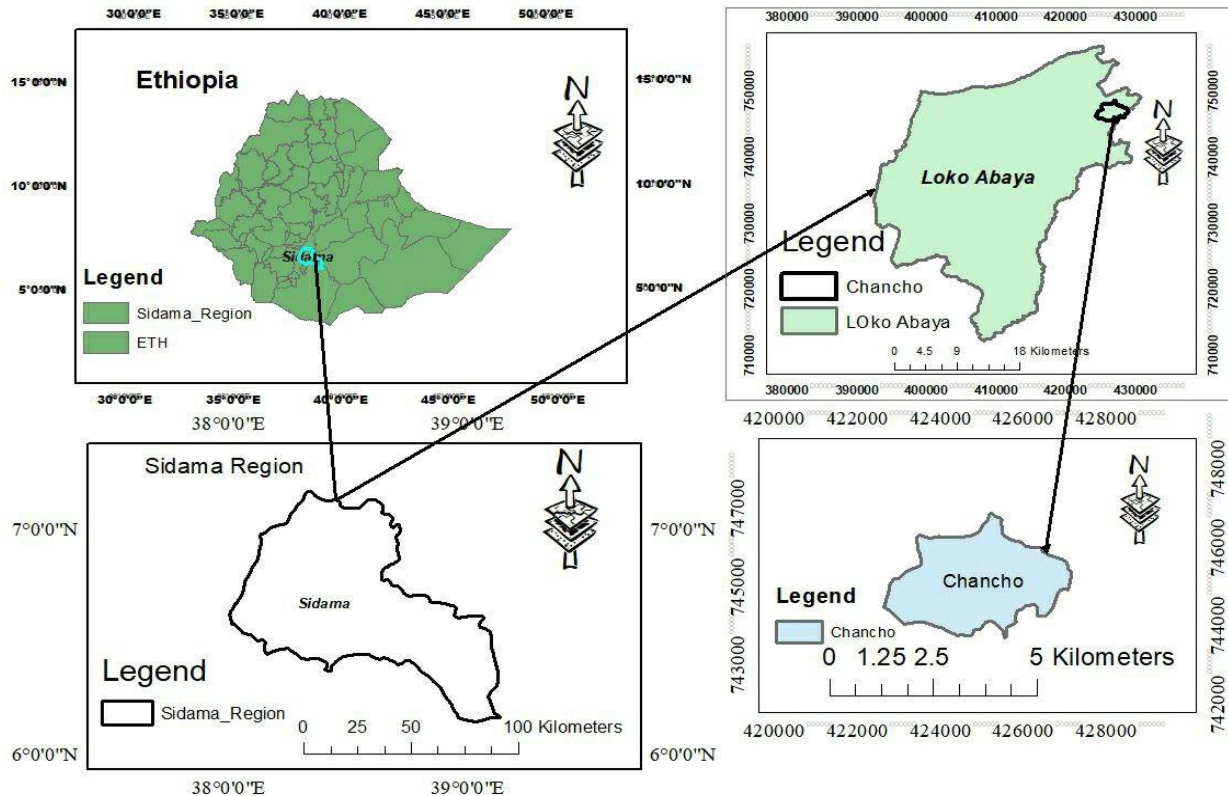


Figure 1 Location map of Chancho small scale irrigation project

3.1.2. Climate

According to long term (1991-2019) record Meteorological data the climate of Chancho reveals that the mean monthly minimum temperature varies from 8.8 to 10.80c and the mean monthly maximum temperature varies from 19.6⁰c to 24.5⁰c respectively. The mean annual rain fall is 1,276.3mm, with mean annual reference evapotranspiration of 1,194.7 mm/annum. The monthly relative humidity varies between 60 to 83%. The wind speed varies from 70 km/day in October to 128 km/day in June. The sunshine hours varies between 4.8 hr/day in July to 8.8 hr/day in October. Rainy season extends from July to end of October and the small rainy season from middle of March through end of June and there has been high evapotranspiration in the area in the November, December, January, February and March, see (Appendix Table 1 and 2).

3.1.3. Crop type

The crops grown in Chanco small-scale irrigation scheme are maize, cabbage, carrot, potato, tomato, onion and chat. The dominant crops of the area grown under irrigation are cabbage, carrot and potato. Most of the products were sold to wholesalers coming from elsewhere to the Dese Kebele. Furrow type of water application method is the method that farmers used to irrigate their land. The types of crops to be grown are selected based on the market condition, the resistance of the crop for disease, water availability and ease of management.

3.2. Material

Materials used for soil sample collection, analysis and discharge measurement purpose are listed in the table below (Table below 3.1)

Table3. 1: Materials used for sample collection and analysis

No	Type of material	Purpose
1	Hammer	To hit the core sampler
2	Core sampler	To collect undisturbed soil samples for soil moisture test
3	Oven dry	To dry soil sample
4	Measuring tape	To measure the dimension of sample pot, sampling pit and canal
5	Plastic bag	To take undisturbed soil sample
6	Auger	To dig soil samples for texture analysis
7	Stop watch	To know the time taken water passing through known distance
8	Weight balance	To measure weight of soil moisture at wet and dry condition
9	Par shall flume	To measure the rate of flowing water in the field canal
10	GPS	To collect different coordinate points
11	Water level	To check the slope of Par shall flume

3.3. Lay out of sample field

Three farmers' fields were selected to undertake evaluation of the irrigation scheme performance. These three farmers' fields were selected from the head, middle and tail end of the command area. The sample field plots were selected based on the availability of water reaching from the conveyance system or distance from the water source to the command area. The size of

the selected fields were measured and field preparations made according to the existing farmers' practices and performance of the selected farmers' fields was made on irrigation events for each farmer.

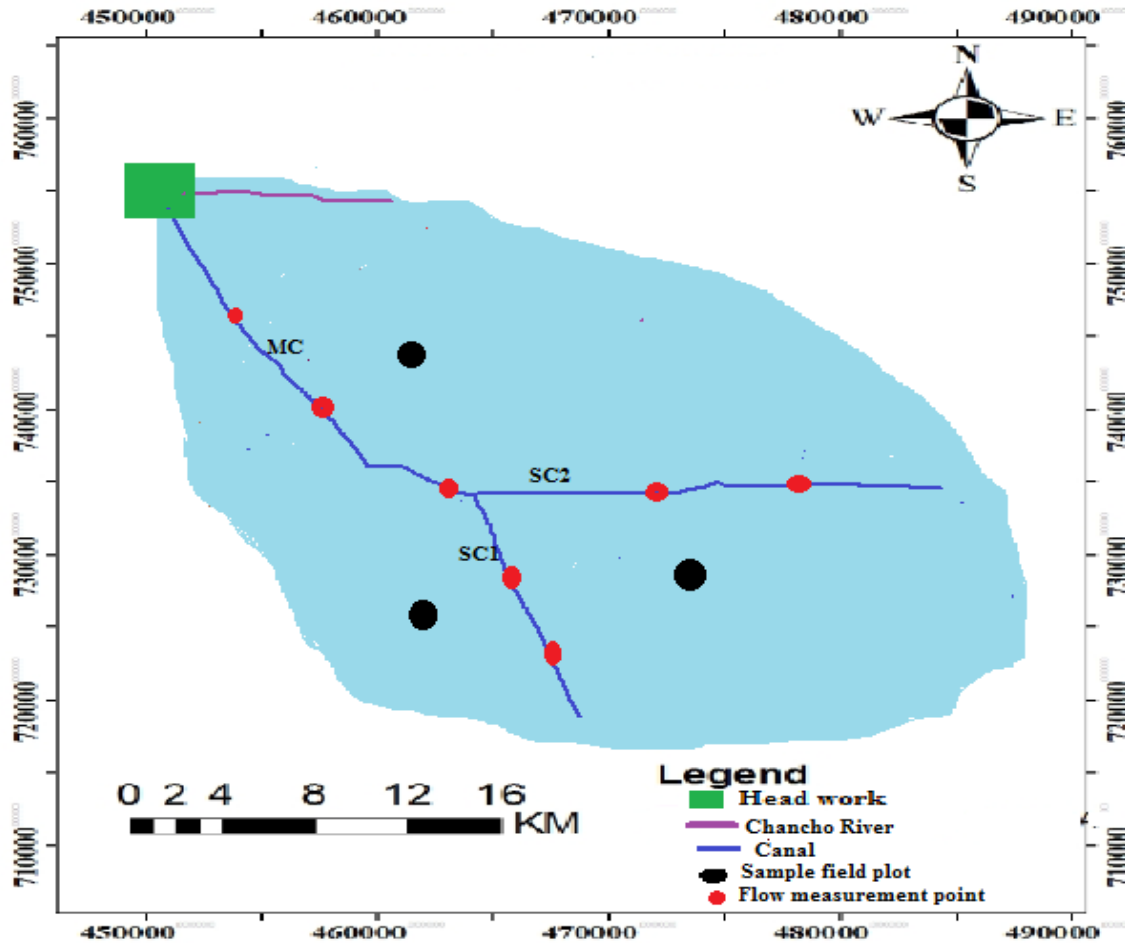


Figure3. 2. Chancho small scale irrigation scheme layout

3.4 .Method of data collection

3.4.1. Primary data collection

Primary data were collected directly from the field observation irrigation scheme status of using transect walk along the scheme. Flow data in the canals and the chosen plots as well as duration of each sampled irrigation and amount of water each selected farmer diverted to his plot for a given irrigation event were obtained through measurements. Soil data were also collected from laboratory measurements specifically on soil water content at field capacity and permanent wilting point, soil texture, bulk density and actual soil moisture content before and after

irrigation. Additionally, data on plot sizes and field irrigation run lengths (furrows) were obtained at the sample plots. All secondary and a data collected were organized and analyzed before evaluation.

3.4.2. Secondary data collection

Secondary data were collected from published and unpublished documents, books, working papers of different institutions. For instance, Bureau of Sidama Region Water and Energy Resources, Hawassa meteorological station, Loka abaya Woreda Agriculture Office, and Dese Keble development agent experts.

3.5 .Method of Soil Sample Collection

To collect representative soil samples, the rows were selected along each field and sampling points were identified from the beginning to the end of each row at regular interval. Then, at each selected points of the rows, soil samples were collected from 0-30 cm and 30-60 cm depth. The depth for different crops was taken based on Brouwer et al., (1989), that categorized those crops as shallow rooting crops (30-60cm), medium rooting crops (50-100cm) and deep rooting crops (90-150cm). According to this author, crops like Potatoes, Cabbages and carrot are categorized as shallow rooting crops.

To determine moisture stored in soil and bulk density soil samples were collected before and after irrigation. For the determination of bulk densities, moisture content, soil moisture content at field capacity and permanent wilting point , undisturbed soil samples were collected head, middle and tail fields using soil core samplers. And disturbed soil samples were collected to determine soil textures, and samples were taken to Hawassa soil testing laboratory.

3.6. Soil sample Analysis

A. Soil moisture Content

Weight basis moisture content of the soil before irrigation and moisture content after irrigation has been determined by using gravimetric method.

$$\text{Moisture content(\%)} = \frac{W_w - W_d}{W_d} * 100 \dots \dots \dots (3.1)$$

Where: - W_w is weight of wet soil (gm).

W_d : weight of dry soil (gm)

The water content in the soil was determined in the volume base using the following equation (Jaiswal, 2003)

$$\text{volumetric moisture content \%} = \text{Weight basis moisture content} * \text{bulk density} \dots \dots \dots (3.2)$$

B. Bulk density

The soil bulk density (BD) was determined from undisturbed soil samples using a core sampler of size 5 cm internal diameter and 5 cm height. The soil sample was collected from 0-30 cm and 30-60 cm at three locations along the diagonal of each selected field and oven dried at 105 °C for 24 hours. The bulk density was determined using the following equation (Hillel, 2004). $BD = \frac{M_s}{V_c}$ (3.3)

$$\frac{M_s}{V_c} \dots \dots \dots (3.3)$$

Where: BD: soil bulk-density (g/ cm³)

MS: mass of dry soil (gm.) and

VC: volume of soil in the core sampler (cm³) and

Volume of soil in the core sampler calculated as

$$V_c = A * H \dots \dots \dots (3.4)$$

Where: Vc: volume of soil in the core (cm³)

A: area of core sampler (cm²)

H: height of core sampler (cm)

The area of the core was calculated as equation

$$A = \frac{\pi D^2}{4} \dots \dots \dots (3.5)$$

D: internal diameter of the core (cm)

A: Area of core sampler

C. Soil Texture Determination

For textural analysis of the soil, disturbed soil samples were collected from each scheme at three locations along diagonal of the selected fields of each scheme (head, middle, and tail end) using

soil auger with the depths 0-30cm, 30-60 cm. The reason for selecting soil sample only from head, middle and tail field, due to economic problem as well as time limitation for this study. Particle size distribution was determined using the Bouyoucos Hydrometer method (Bouyoucos, 1962) and the textural class was assigned using USDA textural triangle (See Appendix figure 1 The percentage of sand, silt and clay of the composite soil sample were determined by sieve analysis and hydrometer method. After the percentage of sand, silt, and clay was measured, the soil may be assigned a textural class using the USDA textural triangle. The proportions of the separates in classes commonly used in describing soils are given in the textural triangle. In using the diagram, the points corresponding to the percentages of silt and clay present in the soil under consideration are located on the silt and clay lines respectively. Lines are then projected inward, parallel in the first case to the clay side of the triangle and in the second case parallel to the sand side.

D. Soil Field Capacity and Permanent Wilting Point

Field capacity and permanent wilting point of the soil were analyzed through pressure plate apparatus in the Hawassa soil testing laboratory. Soil samples were saturated for one day and a pressure of 1/3 bar (for field capacity) and 15bars (for permanent wilting point) was exerted until no further change in soil moisture content were observed. After getting soil moisture values, available water holding capacity of the soil were calculated.

3.7. Discharge measurement

To achieve sufficient and equitable delivery of water to the fields it is useful to know the discharge. Flow measurement takes place both conveyance and water application area. Canal discharge were measured by floating method and the field application water was measured by Parshall flume which is horizontally constricted vertical throat in an open channel used to measure the discharge entering into the field.

A. Canal Discharge Measurement

Determination of discharge through main and secondary canals was obtained by float method. The method consists of estimating the average flow velocity and measuring the area of the cross-section, called the “wetted cross-section”. The discharge was calculated by continuity equation.

$$Q = V * A \dots \dots \dots (3.6)$$

Where: - Q: the discharge (m³/s) V: the average flow velocity (m/s)

A: the area of the wetted cross-section (m²).

B. Average flow velocity

To estimate the average flow velocity, the flow velocity of the water at the surface, the surface velocity, *v_s*, was first determined. The surface velocity was determined by measuring the time it takes for a floating object along the canal. The floating object was placed in the center of a canal and the time measurement was repeated four times to avoid mistakes. The stretch of canal used for measurement should be straight and uniform, in order to avoid changes in the velocity and in the area of the cross-section, because any such variation reduces the accuracy of the velocity estimation. To determine the velocity of surface water of the channel, the length of trail section was divided by the average time taken by the float cross it. Since the velocity of the float on the surface of the water was greater than the average velocity of the stream, it was necessary to correct the measurement by multiplying by a constant factor (velocity correction factor) which was usually assumed to be 0.85 (Harrelson, 1994). To obtain the rate of flow, this average velocity (measured velocity * correction factor) was multiplied by the average cross-sectional area of the stream.

To compute the surface velocity, *V_s* the selected length, *L* was divided by the travel time, *t*

$$V_s = \frac{L}{T_{av}} \dots \dots \dots (3.7)$$

Where: *V_s* is the surface velocity (m/s)

L is the distance in meters between selected points and

T_{av} is the average travel time in seconds between selected points

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

$$V = 0.85 * V_s \dots \dots \dots (3.8)$$

Where: *V* is the average flow velocity (m/s);

Vs is the surface velocity (m/s)

C .Area of the wetted cross-section

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

$$A = W * H \text{ ----- (3.9)}$$

Where: A: area of wetted cross-section (m²)

W: surface water width (m)

H: water depth (m)

D. Field Discharge Measurement

The discharge which was applied to the field was measured by standardized size 2 inch parshall flume. To determine the amount of water applied by the irrigators to the field, during an irrigation event, two inch parshall flume was installed at the entrance of test field. Frequent readings were taken when the farmers irrigate the test field. Irrigation was continuing until the farmers thought that enough amount of water is applied to the field. When the irrigator completed irrigating the test field, the average depth of irrigation water passing through the flume and the respective time were recorded for the sizes of test field being irrigated. According to (USBR, 2014.), discharge was computed as:

$$Q = C * H^n \text{ (3.10)}$$

Where: - Q is applied discharge (l/s)

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

C and n are constants to be determined for flume with two-inch throat

3.8. Method of performance Evaluation of the schemes using internal indicator

The performance of irrigation system was determined by the efficiency with which the water is conveyed through the canal and how irrigation is applied to the plots through data collected periodically. In other words based on data obtained periodically from measurements of irrigation

flow and soil moisture, the irrigation system performance was evaluated using internal performance indicators. The indicators are concerned with performance that directly affect water conveyances and water applied effects. The authors noted that performance of an irrigation system cannot be described with any single efficiency term. Taking this into account, efficiencies such as conveyance efficiency and loss, application efficiency, water storage efficiency and water distribution efficiency were considered to evaluate the performance of the irrigation system (Lecina,S.*etal.*, 2005). The measured data for application, storage, and conveyance and distribution efficiency are under farmer’s control. The appropriate of their grand average values are compared to targets of adequate efficiencies which are considered potential achievable values under specific irrigation scheme and used as a reference.

3.8.1. Conveyance Efficiency

The conveyance efficiency and loss were computed for the main and secondary canals to evaluate performance of the conveyance system.

The parameters were assessed through systematic procedure as stated below using inflow-outflow method. The inflow-outflow method is a water balance approach that consists in the direct measurement of the discharge flowing into and out of a reach of sub canal. Comparison of conveyance efficiency was considered against field irrigation practice efficiency of farmers. The comparison helps to determine where efforts might be made. Similarly, the comparison of discharge from the first site and the second site at the inlet and outlet of canals provided an estimate of the conveyance loss, or the decrease in discharge from the first to second measurement.

Finally the results of conveyance efficiency and loss compared to an ideal one and some other similar study findings to judge conveyance performance thereby improvement options.

Conveyance efficiency (E_C) and loss (L_C) were calculated as Michael (1997)

$$E_C = \frac{Q_{out}}{Q_{in}} * 100 \text{ ----- (3.11)}$$

Where: E_C = conveyance efficiency (%)

Q_o = Canal outlet discharge (m^3/s) and

Q_i = Canal inlet discharge (m^3/s)

$$L_C = Q_{in} - Q_{out} \text{ ----- (3.12)}$$

Where: L_c = Conveyance loss

Table 3.2: Indicative values of the conveyance efficiency (%)

Canal length	Earthen Canal			Lined Canal
	Soil type			
	Sand	Loam	Clay	
Long (> 2000m)	60	70	80	95
Medium(200-2000m)	70	75	85	95
Short (< 200m)	80	85	90	95

Source: FAO Training Manual 4

3.8.2. Application efficiency

The application efficiency was computed as the ratio of moisture added to the soil profile due to irrigation to the total water supplied to the farm or the ratio of moisture retained due to irrigation with total water added to the field (Michael, 2008).

$$Ea\% = \frac{D_s}{D_a} * 100 \dots \dots \dots (3.13)$$

Where: E_a is application efficiency (%),

D_s is depth of water applied to the root zone as storage (mm), and

D_a depth of water applied to the field (mm)

The depth of water retained (stored) in the soil profile of the root zone, D_s , and the total depth applied to the field, D_a , was determined by using the following equations (Michael, 2008).

$$D_a = \frac{Q\Delta t}{A} \dots \dots \dots (3.14)$$

Depth of water applied to the field (mm) Where: - Q is stream size during the irrigation (m^3/s)

Δt is duration of the irrigation (s)

A is area irrigated (m^2)

Table 3.3: Indicative values of the field application efficiency

Irrigation methods Field	Application efficiency (%)
Surface irrigation (border, furrow, basin)	60
Sprinkler irrigation	75
Drip irrigation	90

Source: FAO Training Manual 4

3.8.3 .Water storage efficiency

To evaluate how effectively the irrigation practices satisfied the water requirement of the soil to compensate the moisture depleted by evapotranspiration, the evaluation parameter called water storage (requirement) efficiency calculated using equation (Michael, 2008).

$$Es(\%) = \frac{D_s}{D_{req}} * 100 \quad \text{-----} \quad (3.15)$$

Where: -

D_s is amount of water added to (stored in) the root zone during the irrigation (mm)

D_{req} is amount of water potentially required to fill the root zone to field capacity (mm)

3.8.4. Distribution uniformity

Distribution uniformity is used to measure the variation or non-uniformity of water applied to the entire field. For calculating distribution uniformity, the effective root depth of the crop (i.e., up to 60 cm) was taken as the zone of water distribution. After calculating the depth of water stored (as the difference between the after and before moisture contents) in the top soil (0-30 cm) and sub-soil (30-60 cm), the depth of water stored at each particular sampling point was calculated as the sum of the two.

Distribution uniformity was evaluated based on mean values of the total soil moisture contents stored at the sampling points. The depths of water stored at each sampling point were arranged in descending order and distribution uniformity was determined.

The Distribution uniformity is defined as the percentage of average application amount received in the least-watered quarter of the field. It is the ratio of the average depth Infiltrated in the lower quarter of observations to the average depth of all observations (Rogers., et al 1997).

$$DU(\%) = \frac{\text{mean of lower quarter depth of water stored (mm)}}{\text{mean depth of all water stored (mm)}} * 100 \dots \dots \dots (3.16)$$

According to Eisenhauer (1997) distribution efficiency, ($Du \leq 60\%$ indicates that the irrigation water is unevenly distributed, while ($Du \geq 60\%$) indicates that the application is relatively uniform over the entire field.

3.8.5. Irrigation Efficiency

Scheme Irrigation efficiency (SIE) can be calculated, using the following formula (FAO, 1989; Brouwer et al., 1989)

$$IE = \frac{Ec * Ea}{100} \dots \dots \dots (3.17)$$

Where: - IE is scheme irrigation efficiency (%)
 Ec is conveyance efficiency (%), and
 Ea is field application efficiency (%)

A scheme irrigation efficiency of 50-60% is good; 40% is reasonable, while a scheme Irrigation efficiency of 20-30% is poor (Brouwer et al., 1989).

3.8.6. Deep Percolation Ratio

Deep percolation ratio can be calculated indirectly from values of application efficiency and runoff ratio as given by:

$$DPR = 100 - Ea - RR \dots \dots \dots (3.18)$$

Where: Ea is field application efficiency (%)
 RR is runoff ratio (%)

3.9. To determine irrigation practices of farmers in the scheme

3.9.1. Irrigation water application depth

To determine the depth of application, the soil’s moisture content after irrigation was tested by gravimetric method. The application depth in the fields was estimated after observing irrigation event. Application depth is one of important indicators in evaluation of water management in every irrigation systems. It is dependent on the physical characteristics of the soil under

irrigation. The depth of application per irrigation is the amount of water added to the root zone in irrigation event.

The irrigation depth stored within crop root zone as farmers' practices has been determined by using equation given by (Michael, 2008).

$$D_s = \sum_{i=1}^n \frac{(W_{ai} - W_{bi})}{100} * B_{Di} * D_i \dots \dots \dots (3.19)$$

Where:-

- D_s is average depth of water applied to the root zone as storage (mm),
- W_{ai} is moisture content of the ith layer of the soil after irrigation on oven-dry weight basis, (%)
- W_{bi} is moisture content of the ith layer of soil before irrigation on oven-dry weight basis, (%)
- B_{Di} is bulk density of ith layer of soil
- D_i is depth of ith layer of the soil
- n is number of layers in the root zone

3.9.2. Depth of irrigation water required

Depth of irrigation water that would be required to fill root zone to field capacity was determine using equation given by (Abebe et al, 2013).

$$D_{req} = \sum_{i=1}^n \frac{(W_{fci} - W_{bi})}{100} * B_{Di} * D_i \dots \dots \dots (3.20)$$

Where:-

- D_{req} is amount of water potentially required to fill the root zone to field capacity (mm)
- W_{fci} is moisture content of the ith layer of the soil at field capacity (FC) on oven-dry weight basis (%)
- W_{bi} is moisture content of the ith layer of soil before irrigation on oven-dry weight basis (%)
- D_i is root depth (m).
- B_{Di} is bulk density of ith layer of soil
- n is number of layers in the root zone

3.9.3. Irrigation Interval

For determination of irrigation interval of the irrigation schemes and to make comparison with the current irrigation practices of farmer’s; moisture content at field capacity, permanent wilting point, depletion fraction at each growing stage, total available water and readily available water data were collected. Additionally Irrigation interval of farmer’s was determined from field during irrigation event as farmer’s practice and Irrigation Interval of farmer would be required was determined based on readily available water.

Total available water (TAW) for crop use in the root zone was calculated using Allen et al., 1998) equation.

The total available water in percent based:

$$TAW\% = FC\% - PWP\% \dots\dots\dots(3.21)$$

- Where: TAW (%): total available water in percent
- FC%: soil moisture at field capacity in percent
- PWP%: soil moisture at permanent wilting point in percent

Total available water content in volumetric based:

$$TAW = 1000 \sum (\theta_{FC} - \theta_{PWP}) * Z_r \dots\dots\dots(3.22)$$

- Where: TAW: volumetric total available water in the root zone (mm)
- FC: volumetric moisture content at field capacity (m³/m³) and
- PWP: volumetric moisture content at permanent wilting point (m³/m³)
- Z_r: root zone depth (m)

Readily Available Water was calculated as

$$RAW = TAW * P \dots\dots\dots(3.23)$$

- Where: RAW: Readily available water (mm)
- P: water depletion fraction/management allowable depletion (%).

The irrigation intervals of crops were determined through following equations (Michael, 2008).

$$I = \frac{RAW}{ETc} \text{-----} (3.24)$$

Where: I: irrigation interval (days)

RAW: Readily available water (mm)

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

3.10. Crop water requirement

Determination of crop water requirements is needed to know how much of the applied irrigation water is consumed by the crop. The crop water requirement of the major irrigated crops grown in the irrigation scheme was estimated using CROPWAT 8.0 model. The determination of the CWR by the model depends on the determination of the reference evapotranspiration value using the available climatic data. Data for major crops grown in the study areas including growing stages and stage lengths (days), crop coefficients (Kc), rooting depths (Rdz), depletion levels (P), yield response factors (KY) and planting date were obtained from FAO guidelines (Allen et al., 1998).

Crop water requirement or ETc can be calculated as

$$ETc = Kc * ETO \text{-----} (3.25)$$

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

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

ETO: reference evapotranspiration (mm/day).

4. RESULT AND DISCUSSION

4.1. Analysis of soil physical properties

Soil samples were taken at depth interval of (0-30 and 30-60cm) to investigate the physical properties of the irrigation scheme at different location. From the sampled soil texture, bulk density, field capacity (FC), and permanent wilting point (PWP) were analyzed.

4.1.1. Particle size distribution and textural class

Based on laboratory analysis of particle size distribution, the textural classes of irrigation schemes were determined. As indicated in Table 4.1 Sandy loam is found in the field selected from head and field selected from tail of the scheme; where as in the field selected from middle of the scheme sand soil is found at the top layer and sandy loam soil is found in the lower layer. Based on laboratory analysis and observation of the soil textural classes is dominated by sandy loam.

Table4.1: Soil physical characteristics of irrigation scheme

Sample Field	soil depth(cm)	Particle size distribution			Textural class
		Sand (%)	Clay (%)	Silt (%)	
Head	0-30	69	7	24	Sandy loam
	30-60	80	8	12	Loamy sand
Middle	0-30	78	11	11	Sand
	30-60	60	15	25	Sandy loam
Tail	0-30	60	4	36	Sandy loam
	30-60	72	3	25	Loamy sand

4.1.2. Bulk density

In the irrigation scheme as indicated in Table 4.2 values of bulk density was 1.16, 1.19 and 1.23gm/cm³ at the top layer depth 0-30 cm of the soil for head, middle and tail end of irrigated area respectively and 1.26, 1.16 and 1.27gm/cm³ at the lower layer depth 30-60 cm of the soil for head, middle and tail end of irrigation area respectively. Average soil bulk density of the study area was obtained 1.19gm/cm³ for 0-30cm and 1.23gm/cm³ for 30-60 cm soil depth. The lower layer of the soil bulk density had larger than the top soil. This indicated that the subsurface soil might have lower organic matters content and compacted due to the overlaying by the upper soil materials. Generally this revealed that the subsurface soils have lower soil porosity than surface soil. The overall results of the bulk density of the study area was in the interval for the ideal bulk density for plant growth which is less than or equal to 1.4gm/cm³ for the same soil texture reported by USDA-NRCS, (2014).

4.1.3. Moisture contents at field capacity, permanent wilting point and total available water

The values of field capacity (FC), permanent wilting point (PWP) and total available water content (TAW) are indicated in Table 4.2. The average field capacity and permanent wilting point of the soil was found to be 40.4 and 25.8 on volume basis, respectively. The result of total available water of the soil in the head, middle, and tail field were 131.1, 65.61 and 65.34mm respectively. The total available water (TAW) is directly related to variation in FC and PWP. As a result, high values of TAW were found in topsoil, whereas lower values were found in the subsurface soils. The result indicated that the moisture content is decreased from top to subsurface due to surface soil holds high moisture content than subsurface soil.

Table 4.2: Soil physical characteristics of irrigation scheme

Sample Field	soil depth(cm)	Bulk density(g/cm ³)	FC (%)	PWP (%)	TAW (%)	TAW (mm)	TAW in soil (mm)
Head	0-30	1.16	43.25	18.24	25.01	75.03	131.1
	30-60	1.26	41.5	22.82	18.68	56.04	
Middle	0-30	1.19	38.65	28.32	10.33	30.99	65.61
	30-60	1.16	39.32	27.78	11.54	34.62	
Tail	0-30	1.23	39.20	26.31	12.89	38.67	65.34
	30-60	1.27	40.5	31.61	8.89	26.67	

4.2. Performance Evaluation

4.2.1. Conveyance efficiency and loss

The parameters assessed for efficiency indicator of the conveyance system (main and secondary canals) were conveyance efficiency and loss. The conveyance efficiencies were different for each sub canal section. It ranges from 59.46-71.9% and the minimum one occurred at the main canal during second observation. The conveyance efficiency of the main and secondary canals estimated during this study is presented in table 4.3 and 4.4 respectively. As seen in table 4.3, the conveyance efficiencies for main canal measured for 0.8km lengths during first and second trial were 71.9 and 59.46 respectively with an average value of 65.68%.

On the other hand the average amount of water lost in the main canal was estimated to be 0.0231m³/s (23.1L/sec) over 0.8km length and amount to 831.6 m³ with 10hrs average length of time that the water flows in this main canal along a 0.8km length. This means the canal wastes 2.90L/sec water at every 100m canal segment (2.90ls⁻¹/100m). This result is much comparable with similar research finding in Ethiopia; Sisay et al. (2009) reported about 2.58ls⁻¹/100m water loss from lined main canal of average 43.21 ls⁻¹ flow rate capacity in Blue Nile and that of average conveyance water lose 0.014 ls⁻¹/m obtained from lined main canal of 22.95 l/s average flow rate in South Wollo Zone (Henok Tesfaye and Kedir Jemal, 2020).

Loss of irrigation water in the main canal conveyance system during the second observation was found to be greater than loss of irrigation water during the first observation. The reason was that during the second irrigation event farmers release large amount of water from the reservoir and much of water loss through overtopping of buried canal section and water loving weeds were reached to their full growth during this time.

For the secondary canals #1 and #2 average conveyance efficiencies were 65.61% and 64.09 % respectively. On the other hand in the secondary canal #1 the average amount of water lost was $0.011\text{m}^3/\text{s}$ (11ls^{-1}) per 0.7km whereas in the secondary canal#2 was $0.0086\text{ m}^3/\text{s}$ (8.6ls^{-1}) per 0.9 km. Generally average conveyance loss in the main canal was found to be greater than the sum of average conveyance loss in the secondary canals. The reason is attributed to the presence of buried canal sections along the main canal and hence much overtop flow appear. According to FAO (1989), the conveyance efficiency of lined canals has been reported in the order of 95% for all canal length, but in the Chanco scheme the grand average value of conveyance efficiency was 65.1% which is not efficient compared to the above finding. The loss resulted from leaks, over top flows, cover with soil and water love vegetation growth on the canals. In view of this finding, it is important to focus on targeting efficient water conveyance.

Table 4.3: Computed conveyance loss and efficiency of the main canal over 0.8km.

Observations	Canal section code	Avg flow depth (m)	Canal width (m)	Cross section area (m^2)	Length of sub canal considered(m)	Average time elapsed (sec)	Average velocity (m/sec)	Discharge (m^3/sec)	Conveyance loss (m^3/s) ($Q_I - Q_0$)	Conveyance Efficiency (%)
1st	UMCS	0.08	1	0.08	32	38	0.716	0.057	0.016	71.9
	LMCS	0.07	1	0.07	32	47	0.580	0.041		
2nd	UMCS	0.095	1	0.095	32	35	0.777	0.074	0.03	59.46
	LMCS	0.066	1	0.066	32	41	0.663	0.044	Av=0.0231	Av=65.68

Note: Velocity s multiplied by correction factor of 0.85.

UMCS= upper main canal section where inlet discharge (Q_I) was measured

LMCS= lower main canal section where outlet discharge (Q_0) was measured

Av=average value

Table 4.4: Computed conveyance efficiency and loss of the secondary canal 1 and 2 over 0.7km and 0.9 km length respectively.

Observation	Canal section code	Avg flow depth (m)	Canal width (m)	Cross section area (m ²)	Length of sub canal (m)	Average time elapsed (sec)	Average velocity (m/sec)	Discharge (m ³ /sec)	Conveyance loss (m ³ /s) (Q _I - Q ₀)	Conveyance Efficiency (%)
1st	USCS #1	0.075	0.7	0.053	32	42	0.65	0.034	0.013	61.7
	LSCS#1	0.055	0.7	0.038	32	50	0.544	0.021		
2nd	USCS #1	0.084	0.7	0.0588	32	39	0.697	0.041	0.0137	66.6
	LSCS#1	0.069	0.7	0.0483	32	48	0.566	0.0273	Av=0.013	Av=64.1
1st	USCS #2	0.062	0.5	0.031	32	39	0.697	0.0216	0.0069	68.0
	LSCS#2	0.053	0.5	0.026	32	48	0.566	0.0147		
2nd	USCS #2	0.071	0.5	0.0468	32	45	0.604	0.028	0.0104	62.8
	LSCS#2	0.052	0.5	0.033	32	51	0.533	0.0176	Av=0.0086	Av=65.4

Note: velocity was multiplied by correction factor of 0.85.

USCS = upper secondary canal section where inlet discharge (Q_I) was measured

LSCS= lower secondary canal section where outlet discharge (Q₀) was measure.

4.2.2. Application Efficiency

The application efficiency was estimated using equation 3.13 and presented in able 4.5. The results were found 49.3, 51.4 and 68.7% for the Head, Middle and Tail field of the irrigation scheme respectively. According to FAO (1989) water application efficiency for furrow irrigation method is ranged 60-70%. Whereas according Rogers et al. (1997) revealed that furrow irrigation methods have wider range of application efficiency i.e.50-90%. The result indicates

that at the head field the farmers use long furrow and excess application time .due to this the head field was less efficient relatively to the middle and tail irrigation fields. The tail end field were efficient than the head and middle field this is due to short application time and less water application. On over all bases of the values of application efficiency for Chanco irrigation scheme was indicates less efficient.

Table4.5: application efficiency

Sampled field	Applied depth(Da) in mm	Depth stored(Ds) in(mm)	Application efficiency (%)
Head	105.4	52.02	49.3
Middle	84.6	43.5	51.4
Tail	83.1	57.1	68.7
	Scheme application efficiency		56.5

4.2.3. Storage Efficiency

The storage efficiency computed using equation 3.15 and result is displayed in Table 4.6. The storage efficiency varied from 80.2 to 87.7% with an average value of 83.9%. This indicated that the storage efficiency at Chanco SSIS is lower than 90.2 to 96.8% for Midhegdu Small-scale Irrigation Scheme reported by Worku, (2013). The result implies that about 83.9% of the Chanco irrigation schemes satisfies moisture deficit of crop root zone and irrigation water application is not successfully met its objective of refilling the root zone to field capacity. The storage efficiency of schemes is poor. this is due to soil at the sample field was mainly sandy loam and sand which has a low water holding capacity, excessive seepage loss form part of the problems and application of inappropriate flow rate with excess application time. The calculated value of storage efficiency at tail field was higher than head and middle fields.

Table4.6: Storage efficiency of the irrigation scheme

Sample plot	Stored water (mm)	Required water(mm)	Storage efficiency (%)
Head	52.02	62.4	83.4
Middle	43.5	54.2	80.2
Tail	57.1	65.1	87.7

4.2.4. Distribution Uniformity

The DU of the scheme was calculated using equation 3.16 and result is displayed in Table 4.7. The results were found 72.6, 66.2 and 75.2% for the Head, Middle and Tail field of the irrigation scheme respectively. From the results observed, there were relatively good distribution uniformity at middle field, at the head and tail field of the irrigation scheme. But, at the head and tail field of irrigation schemes were better distribution uniformity compared with at middle field. According to the typical recommended result by Eisenhauer (1997) distribution uniformity greater than 60% is acceptable. According to this guide line water distribution uniformity is relatively efficient and uniform over the entire field.

Table4.7: Distribution Uniformity of the irrigation scheme

Sample plot	Mean of lower quarter depth of water stored(mm)	Mean of all water stored(mm)	Distribution Uniformity (%)
Head	33.5	46.1	72.6
Middle	39.9	60.25	66.2
Tail	36.9	49.04	75.2

4.2.5. Deep Percolation Ratio

The deep percolation of the scheme was calculated using equation 3.18 described in section 3.8.6. Farmers were practicing closed end furrow, only deep percolation loss was considered. The results were found 50.7, 48.6 and 31.3% with average values of 43.5% for the Head, Middle and Tail field of the irrigation scheme respectively. According to FAO (1998) water loss through deep percolation and surface runoff could be about less than 10%. Highest deep

percolation loss recorded at the head and middle of the scheme. This is due to excess water application time and flow rate for the sand and sandy loam soil which contributes to the deep percolation loss. This result shows that deep percolation loss is considered as unacceptable and water is lost from the field in the form of deep percolation.

4.2.6. Scheme Irrigation Efficiency

The overall efficiency of the scheme is the product of conveyance efficiency and application efficiency and estimated using equation 3.17. The overall efficiencies of scheme were found to be 36.8%. According to FAO (1989) a scheme irrigation efficiency of 50-60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20-30% is poor and according to this guide line the performance of Chanco irrigation schemes were relatively poor.

4.3. Evaluation of irrigation practices of the farmers

4.3.1. Depth of irrigation

The farmer's application depth of irrigation water and depth of irrigation water that would be required to fill root zone to field capacity estimated using equation 3.19 and 3.20 respectively. And results are indicated in table 4.8. In the Head, Middle and Tail field of the irrigation scheme farmer's application depth were 52.02, 43.5 and 57.1mm respectively. And depths of irrigation that would be applied were 62.4, 54.2 and 65.1mm respectively. This result shows that farmer is not applying required depth at head and middle field. In the tail field depth of irrigation water applied by the farmer is better compared with head and middle field.

Table4.8: depth of irrigation applied by farmer and required depth

Sample plot	Soil depth(cm)	Depth would be applied(mm)	Farmer applied depth(mm)
Head	60	62.4	52.02
Middle	60	54.2	43.5
Tail	60	65.1	57.1

4.3.2. Irrigation Interval

Irrigation interval was calculated using equation 3.24 described in section 3.9.3. The result shows that calculated and farmers practiced irrigation intervals were varying in sampled crops.

Farmers were applying the same irrigation interval in each growth stage of the irrigated crop but crops require different irrigation intervals in each growth stage. Crop water requirement vary depends on growth stage. Calculated irrigation interval at the head field shows greater difference than tail and middle field. As a result of applied the same irrigation interval throughout the growth stage, irrigated crop production would have declined. As result, farmer increase irrigation interval.

Table4.9: Farmers practiced and calculated irrigation intervals

Sample field	Crop type	TAW (mm)	depletion fraction(P)	RAW (mm)	ETc (mm/day)	Calculated Irrigation interval(in days)	Irrigation interval practiced (in days)
Head	Cabbage	131.1	0.45	58.99	3.96	15	6
Middle	Potato	65.61	0.35	23.01	4.03	6	4
Tail	Carrot	65.34	0.35	22.86	3.84	6	5

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

This study was conducted to evaluate the performance of Chanco Small-Scale Irrigation Scheme in Loka abaya woreda, Sidama Regional State of Ethiopia, using internal performance indicators and irrigation water management practices of farmer of the scheme. To achieve the objectives primary and secondary data were collected. Primary data collected and incorporated to field observations, measurements of flow rate in the canals and at field level, determination of moisture content of the soils at selected irrigation fields before and day after irrigations. Discharge measurement in the canal and sampled field were determined using Float method and par shall flume. Secondary data was collected from published and unpublished documents, books, working papers of different institutions such as Meteorological station, Loka abaya Woreda Agriculture Office, and Keble development agent experts.

The internal performance indicators used were include conveyance, application, storage and distribution efficiencies, runoff ratio, deep percolation ratio and overall irrigation efficiency were used to evaluate the performance of the irrigation scheme.

The average conveyance efficiency and loss were found to be 65.1% and 34.9% respectively. During the study period, water was seen to be lost at several chosen plots signifying that the water conveyance system was inadequate and poorly maintained. The presence of buried canal segments result over flow, lack of frequent canal cleaning, illegal breaching of canal and poor maintenance of canals contributed for low conveyance efficiency or large water loss. So to manage these issues effective canal maintenance and frequent canal cleaning should be done on the conveyance system.

The study showed that the application efficiencies of head, middle and tail end of selected fields were 49.3, 51.4 and 68.7%, respectively. The result indicates that at the head field the farmers were applying excess amount of water to their field due to this the head field was less efficient relatively to the middle and tail irrigation fields. Low efficiencies were achieved due to the fact that poor water management by the farmers at field level. The values of application efficiency for the scheme were less efficient.

The result of Storage efficiency of the scheme shows that of the schemes satisfies 83.9% of moisture deficit of crop root zone and irrigation water application is not successfully met its objective of refilling the root zone to field capacity. The distribution uniformity at the head, middle and tail field was 72.6, 66.2, and 75.2% respectively. This indicates the applied irrigation depth was evenly distributed to the irrigated crops. From the applied water, about 43.5% was lost due to deep percolation this indicates that farmer irrigated field with excess application time and flow rate for sandy soil. Overall scheme efficiency was 36.8%. Based on the above observation overall efficiency of irrigation schemes were categorized under low efficiency.

The farmer's application depth of irrigation water and depth of irrigation water that would be required to fill root zone to field capacity estimated. Evaluated result shows that farmer is not applying required depth for their soil in the head and tail field. Farmers practiced and calculated irrigation intervals were varying in sampled crops. Farmers were applying the same irrigation interval in each growth stage of the irrigated crop but crops are required different amount of water at different irrigation interval within each growth stage. According to the results obtained, water management practice of the scheme was poor.

Generally, based on evaluation findings the scheme requires improvement measures to maximize its performance and to achieve construction goals and targets. Therefore, irrigation management and practice, frequent performance evaluation should be conducted to identify the critical level of the schemes.

5.2. Recommendations

Based on the study results, the following recommendations were suggested:

- ✓ Water conveyance efficiencies are low. Therefore, it is better to improve efficiency of canal through regular cleaning, lining where more leakage loss occurred and by reducing illegal abstraction water by breaching canal.
- ✓ Continuous monitoring and evaluation of the scheme are necessary to take immediate correction action to improve conveyance efficiencies.
- ✓ Application efficiency was low .It should be increased by applying appropriate discharge and application time to improve application efficiency.
- ✓ Farmer's application depth is not line with required depth. It should be increase depth of application by adjusting applied discharge and time.
- ✓ Irrigation intervals of farmer are inappropriate. It should be increase irrigation interval.
- ✓ Scheme irrigation efficiency is poor. Therefore, maintenance of canal water conveyance system of the scheme and regular capacity building training on over all irrigation water management, scheme operation and maintenance should be given to beneficiary farmers.
- ✓ Assigning irrigation expert to the scheme and conducting on-job training of farmers to the improvement of the scheme performance.
- ✓ Aware the farmers' on how managed the irrigation water during transportation of water from the source to the farm field during irrigation time.

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APPENDICES

Appendix Table 1: Climate data for study area from 1991 to 2019

Month	Min Temp (°C)	Max Temp (°C)	Humidity (%)	Wind (km/day)	Sunshine Hour (hr)	Rad (MJ/m ² /day)	ETo	
							mm/day	mm/month
January	9.6	23.6	67	102	9.4	20.42	3.56	106.8
February	9.8	24.5	63	102	9	21.53	3.62	107.6
March	10.5	23.5	68	126	7.6	20.86	3.64	108.2
April	10.6	21.9	77	102	7.6	21.34	3.6	108.4
May	10.8	21.5	79	102	7.3	19.64	3.34	100.20
June	9.9	21.5	82	128	6.6	18.5	3.06	91.80
July	9.5	19.6	80	102	4.8	16.4	2.68	80.4
August	9.3	19.8	79	104	5.5	17.2	2.86	85.43
September	10.2	20.8	83	66	6.4	18.34	3.16	94.32
October	9.6	20.9	72	66	7.2	19.65	3.33	101.53
November	9.4	21.9	71	82	8.8	20.95	3.45	103.56
December	8.8	22.9	60	88	8.4	19.86	3.44	106.45
Average/Total	10.8	22	73.4	97.5	7.38	19.56	3.33	1,194.7

Appendix Table 2: Mean monthly rainfall and effective rainfall

Months	Rain fall(mm)	Effective rain fail(mm)
January	36.3	33.3
February	33.2	31.0
March	71	63.2
April	177.3	122.5
May	195.5	131.0
June	120.4	95.6
July	98.5	81.2

August	153.1	111.6
September	139.0	105.0
October	168.5	121.4
November	63.1	55.3
December	20.4	17.5
Average/Total	1,276.3	968.6

Appendix Table 3: Monthly distributions of reference evapotranspiration (ET_o in mm/month) and mean monthly rainfall (mm)

Months	ET _o	Rainfall
January	106.8	36.3
February	107.6	33.2
March	108.2	61
April	108.4	177.3
May	100.20	195.5
June	91.80	120.4
July	80.4	98.5
August	85.43	153.5
September	94.32	139.0
October	101.53	168.5
November	103.56	63.1
December	106.45	20.4
Total	1,194.7	1,276.3

Appendix Table 1: Soil moisture content before irrigation

Sample	Soil	Before irrigation	Volume	Bulk	Moisture	Moisture
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field	depth(cm)	Wet weight (gm)	Dry weight (gm)	of core(cm ³)	Density (g/cm ³)	before Irrigation (θ g%)	before irrigation (vol %)
Head	0-30	150.32	115.4	98.125	1.16	30.2	35.0
	30-60	153.40	124.5	98.125	1.26	23.2	29.2
Middle	0-30	145.52	118.0	98.125	1.19	23.3	27.7
	30-60	147.52	115.45	98.125	1.16	27.7	32.2
Tail	0-30	151.74	121.5	98.125	1.23	24.9	30.6
	30-60	153.46	125.56	98.125	1.27	22.2	28.2

Appendix Table 2: Soil moisture content after irrigation

Sample field	Soil depth(cm)	After irrigation		Volume of core(cm ³)	Bulk density (g/cm ³)	Moisture after irrigation (g %)	Moisture after irrigation (vol %)
		Wet weight (gm)	Dry weight (gm)				
Head	0-30	156.56	113.45	98.125	1.15	37.9	43.5
	30-60	161.86	124.32	98.125	1.26	30.2	38.05
Middle	0-30	150.23	114.35	98.125	1.16	31.4	36.4
	30-60	151.21	113.84	98.125	1.16	32.8	38.0
Tail	0-30	157.43	118.42	98.125	1.20	33.04	39.6
	30-60	160.43	122.56	98.125	1.24	30.9	38.3

.Appendix Table 3: Total Moisture stored in root zone

Sample field	Soil depth (cm)	Moisture before irrigation (Vol %)	Moisture after irrigation (Vol %)	Moisture Stored (Vol %)	Moisture stored in depth(mm)	Total Moisture stored in root zone (mm)
Head	0-30	35.0	43.5	8.5	25.5	52.05
	30-60	29.2	38.05	8.85	26.55	
Middle	0-30	27.7	36.4	8.7	26.1	43.5
	30-60	32.2	38.0	5.8	17.4	

Tail	0-30	30.6	39.6	9.0	27	57.1
	30-60	28.2	38.3	10.1	30.1	

Appendix Table 4: Depth of water applied to the field

Sample plot	H-Flume height (cm)	c-free flow coefficient	n-free flow exponent	Applied discharge (l/s)=C*H ⁿ
Head	10.5	0.1205	1.55	4.7
Middle	9	0.1205	1.55	3.7
Tail	8.5	0.1205	1.55	3.4

Appendix Table 5: Application efficiency

Sampled field	Applied discharge (l/s)	Time elapsed (sec)	Area of field (m ²)	Total volume (l)	Applied depth (Da) in mm	Depth stored (Ds) in Mm	Application efficiency (%)
Head	4.7	8280	370	38,916	105.4	52.05	49.3
Middle	3.7	7390	320	27,343	84.6	43.5	51.4
Tail	3.4	7358	300	25,017.2	83.1	57.1	68.7

Appendix Table 6: Required water to fill root zone to field capacity

Sample plot	Soil depth	Soil moisture content at (FC)	Soil moisture content before irrigation (Wbi)	Required depth (mm)	Total required water in depth
Head	0-30	43.25	35	25.5	62.4
	30-60	41.5	29.2	36.9	
Middle	0-30	38.65	27.7	32.85	54.2
	30-60	39.32	32.2	21.4	
Tail	0-30	39.20	30.6	25.8	65.1
	30-60	40.5	28.2	36.9	

Appendix Table 7: Storage efficiency

Sample plot	Soil depth(cm)	Stored water at root zone(mm)	Required water(mm)	Storage efficiency (%)
Head	60	52.02	62.4	83.4
Middle	60	43.5	54.2	80.2
Tail	60	57.1	65.1	87.7

Appendix Table 8: Soil moisture content before irrigation for distribution uniformity of head

Sample field	Soil depth(cm)	Before irrigation		Volume of core(cm ³)	Bulk density (g/cm ³)	Moisture before irrigation (θ g%)	Moisture before irrigation (vol %)
		Wet weight (gm)	Dry weight (gm)				
H1	0-30	152.65	113.64	98.125	1.16	34.3	39.5
	30-60	160.32	122.40	98.125	1.24	30.9	38.3
H2	0-30	159.2	118.2	98.125	1.20	34.7	41.6
	30-60	152.36	115.65	98.125	1.18	32.0	37.4
H3	0-30	153.52	110.84	98.125	1.13	38.5	43.5
	30-60	155.32	116.24	98.125	1.18	33.6	39.6
H4	0-30	161.21	116.84	98.125	1.19	37.9	45.1
	30-60	155.62	118.75	98.125	1.21	31.1	37.5
H5	0-30	153.84	112.32	98.125	1.14	36.9	42.1
	30-60	164.75	124.65	98.125	1.27	32.2	40.9
H6	0-30	157.22	113.46	98.125	1.16	38.5	44.7
	30-60	162.64	121.62	98.125	1.24	33.5	41.2
H7	0-30	164.57	113.86	98.125	1.16	44.4	51.5
	30-60	166.56	125.43	98.125	1.27	32.9	41.7
H8	0-30	162.65	119.86	98.125	1.22	35.6	43.4
	30-60	164.52	127.44	98.125	1.30	29.0	37.7
H9	0-30	159.32	118.84	98.125	1.21	34.0	41.1
	30-60	161.44	125.57	98.125	1.28	28.5	36.5
H10	0-30	159.26	122.5	98.125	1.24	29.9	37.2

	30-60	155.16	119.65	98.125	1.22	29.6	36.2
H11	0-30	154.86	116.43	98.125	1.18	33.0	38.9
	30-60	151.84	113.62	98.125	1.16	33.7	39.2
H12	0-30	159.56	118.23	98.125	1.20	34.9	41.9
	30-60	162.53	123.65	98.125	1.26	32.2	40.5

Appendix Table 9: Soil moisture content after irrigation for distribution uniformity of head field

Sample field	Soil depth(cm)	After irrigation		Volume of core(cm ³)	Bulk Density (g/cm ³)	Moisture After Irrigation (θ_g %)	Moisture After irrigation (vol %)
		Wet weight (gm)	Dry weight (gm)				
H1	0-30	168.57	118.64	98.125	1.21	42.1	50.9
	30-60	166.20	122.32	98.125	1.24	35.8	44.4
H2	0-30	167.26	119.65	98.125	1.22	39.8	48.5
	30-60	165.82	123.21	98.125	1.25	34.6	43.2
H3	0-30	171.43	124.86	98.125	1.27	37.3	47.3
	30-60	172.35	119.82	98.125	1.22	43.8	53.4
H4	0-30	173.67	123.56	98.125	1.26	40.5	51.0
	30-60	172.83	124.84	98.125	1.27	38.4	48.7
H5	0-30	159.46	113.65	98.125	1.16	40.3	46.7
	30-60	170.32	117.62	98.125	1.19	44.8	53.0
H6	0-30	169.56	122.22	98.125	1.23	39.5	48.6
	30-60	170.86	125.82	98.125	1.28	35.8	45.8
H7	0-30	176.45	114.32	98.125	1.16	54.3	62.9
	30-60	178.65	137.52	98.125	1.40	29.9	41.8
H8	0-30	176.56	120.87	98.125	1.23	44.4	54.6
	30-60	179.64	129.82	98.125	1.32	38.4	50.7
H9	0-30	166.24	121.86	98.125	1.24	36.4	45.1
	30-60	167.35	124.32	98.125	1.27	34.6	43.9

H10	0-30	165.46	123.32	98.125	1.25	34.1	42.6
	30-60	172.65	119.87	98.125	1.22	44.0	53.7
H11	0-30	171.45	118.62	98.125	1.19	44.7	53.6
	30-60	160.42	113.83	98.125	1.16	40.9	47.6
H12	0-30	167.74	122.42	98.125	1.24	37.02	45.7
	30-60	171.68	124.42	98.125	1.27	37.9	48.1

Appendix Table 10: Total Moisture stored in root zone of head field

Sample field	Soil depth (cm)	Moisture before irrigation (Vol %)	Moisture after irrigation (Vol %)	Moisture Stored (Vol %)	Moisture stored in depth(mm)	Total Moisture stored in root zone (mm)
H1	0-30	39.5	50.9	11.4	34.2	52.5
	30-60	38.3	44.4	6.1	18.3	
H2	0-30	41.6	48.5	6.9	20.7	37.9
	30-60	37.4	43.2	5.8	17.2	
H3	0-30	43.5	47.3	3.8	11.4	52.8
	30-60	39.6	53.4	13.8	41.4	
H4	0-30	45.1	51.0	5.9	11.7	45.3
	30-60	37.5	48.7	11.2	33.6	
H5	0-30	42.1	46.7	4.6	13.8	50.1
	30-60	40.9	53.0	12.1	36.3	
H6	0-30	44.7	48.6	3.9	11.7	25.5
	30-60	41.2	45.8	4.6	13.8	
H7	0-30	51.5	62.9	11.4	34.2	43.8
	30-60	41.7	44.9	3.2	9.6	
H8	0-30	43.4	54..6	11.2	33.6	72.6

	30-60	37.7	50.7	13	39	
H9	0-30	41.1	45.1	4.2	12.8	35
	30-60	36.5	43.9	7.4	22.2	
H10	0-30	37.2	42.6	5.4	16.2	68.7
	30-60	36.2	53.7	17.5	52.5	
H11	0-30	38.9	53.6	14.7	44.1	66.6
	30-60	39.2	47.6	8.4	25.2	
H12	0-30	41.9	45.7	3.8	11.4	34.2
	30-60	40.5	48.1	7.6	22.8	

Appendix Table 11: Soil moisture content before irrigation for distribution uniformity of middle

Sample field	Soil depth (cm)	Before irrigation		Bulk Density (g/cm ³)	Moisture before Irrigation (θ g%)	Moisture before irrigation (vol %)
		Wet weight (gm)	Dry weight (gm)			
M1	0-30	155.20	112.32	1.14	38.17	43.5
	30-60	158.65	115.43	1.17	37.44	43.8
M2	0-30	158.56	118.34	1.22	33.9	41.3
	30-60	162.86	112.43	1.14	44.8	51.1
M3	0-30	154.82	114.68	1.16	33.3	38.6
	30-60	162.35	125.42	1.27	29.4	37.6
M4	0-30	159.42	122.32	1.24	30.3	37.5
	30-60	165.62	119.46	1.21	38.6	46.7
M5	0-30	160.21	116.84	1.19	37.1	44.1
	30-60	168.86	124.23	1.26	35.9	45.2
M6	0-30	157.15	118.32	1.20	32.8	39.4
	30-60	163.68	115.24	1.17	42.0	49.2

M7	0-30	158.56	113.56	1.15	39.6	45.8
	30-60	164.42	125.34	1.28	31.2	39.9
M8	0-30	162.10	125.23	1.27	27.8	35.3
	30-60	166.20	122.46	1.24	35.7	44.2
M9	0-30	162.22	116.34	1.18	39.4	46.5
	30-60	160.36	120.21	1.22	33.4	40.7
M10	0-30	159.46	122.32	1.24	37.1	46.0
	30-60	163.25	125.65	1.27	29.9	38.0
M11	0-30	158.46	118.34	1.20	40.1	48.1
	30-60	164.45	116.38	1.18	41.3	48.7
M12	0-30	166.42	123.68	1.25	34.5	43.1
	30-60	162.74	115.25	1.17	41.3	48.3

Appendix Table 12: Soil moisture content after irrigation for distribution uniformity of middle

Sample field	Soil depth(cm)	After irrigation		Bulk density(g/cm ³)	Moisture After Irrigation (θ g %)	Moisture After irrigation (Vol %)
		Wet weight (gm)	Dry weight (gm)			
M1	0-30	165.53	113.53	1.15	45.8	52.9
	30-60	168.62	120.12	1.22	40.4	49.4
M2	0-30	169.54	111.45	1.13	52.1	59.2
	30-60	174.35	118.66	1.21	46.9	56.7
M3	0-30	165.56	119.77	1.22	46.9	57.2
	30-60	174.77	128.62	1.31	35.8	47.0
M4	0-30	168.48	118.93	1.21	41.6	50.5
	30-60	176.93	125.84	1.28	40.6	52.1
M5	0-30	170.33	120.65	1.23	41.2	50.6

	30-60	178.86	128.93	1.31	38.7	50.8
M6	0-30	168.53	113.85	1.16	48.1	55.7
	30-60	172.55	115.73	1.17	49.1	57.9
M7	0-30	174.66	120.52	1.22	44.9	55.2
	30-60	179.57	124.64	1.27	44.1	55.9
M8	0-30	174.54	120.56	1.22	44.7	55.0
	30-60	177.61	124.63	1.27	42.5	53.9
M9	0-30	173.42	120.61	1.22	43.7	53.8
	30-60	176.65	125.84	1.28	40.3	51.7
M10	0-30	177.42	120.13	1.22	47.7	58.1
	30-60	167.48	112.78	1.15	48.5	55.2
M11	0-30	171.38	118.64	1.19	44.5	52.9
	30-60	172.67	122.21	1.23	41.3	50.6
M12	0-30	174.43	124.87	1.27	39.8	50.4
	30-60	179.33	122.89	1.24	45.9	56.9

Appendix Table 13: Total Moisture stored in root zone of middle field

Sample field	Soil depth (cm)	Moisture before irrigation (Vol %)	Moisture after irrigation (Vol %)	Moisture Stored (Vol%)	Moisture stored in depth(mm)	Total Moisture stored in root zone (mm)
M1	0-30	43.5	52.9	9.4	28.2	45.0
	30-60	43.8	49.4	5.6	16.8	
M2	0-30	41.3	59.2	17.9	53.7	70.6
	30-60	51.1	56.7	5.6	16.9	
M3	0-30	38.6	57.2	18.6	55.8	84.3
	30-60	37.6	47.0	9.4	28.6	

M4	0-30	37.5	50.5	13.	39	55.2
	30-60	46.7	52.1	5.4	16.2	
M5	0-30	44.1	50.6	6.5	19.5	36.2
	30-60	45.2	50.8	5.6	16.7	
M6	0-30	39.4	55.7	16.3	48.9	75
	30-60	49.2	57.9	8.7	26.1	
M7	0-30	45.8	55.2	9.4	28.4	76.4
	30-60	39.9	55.9	16	48	
M8	0-30	35.3	55.0	19.7	59.1	88.2
	30-60	44.2	53.9	9.7	29.1	
M9	0-30	46.5	53.8	7.3	21.9	54.9
	30-6	40.7	51.7	11	33	
M10	0-30	46.0	58.1	12.1	36.3	88.5
	30-60	38.0	55.4	17.4	52.2	
M11	0-30	48.1	55.9	7.8	23.4	38.4
	30-60	48.7	53.7	5	15	
M12	0-30	43.1	50.4	7.3	22.9	48.7
	30-60	48.3	56.9	8.6	25.8	

Appendix Table 14: Soil moisture content before irrigation for distribution uniformity of tail

Sample field	Soil depth(cm)	Before irrigation		Bulk Density (g/cm ³)	Moisture before irrigation (θ g %)	Moisture before irrigation (Vol %)
		Wet weight (gm)	Dry weight (gm)			
T1	0-30	155.42	112.86	1.15	37.7	43.3
	30-60	160.23	114.62	1.16	39.8	46.2
T2	0-30	150.65	119.56	1.22	26.0	31.6
	30-60	154.23	113.67	1.15	35.6	41.3

T3	0-30	166.15	127.56	1.27	30.2	38.3
	30-60	161.85	121.35	1.23	33.3	41.0
T4	0-30	154.76	112.57	1.14	37.4	42.9
	30-60	158.58	110.57	1.12	43.4	48.9
T5	0-30	152.65	115.66	1.17	31.9	37.6
	30-60	154.31	114.21	1.16	35.1	40.7
T6	0-30	160.67	115.63	1.17	38.9	45.9
	30-60	165.12	121.86	1.24	35.5	44.0
T7	0-30	157.23	111.62	1.13	40.8	46.4
	30-60	164.81	122.53	1.24	34.5	43.1
T8	0-30	161.63	115.65	1.17	39.7	46.8
	30-60	156.65	119.67	1.21	30.9	37.6
T9	0-30	160.22	118.32	1.20	35.4	42.4
	30-60	157.43	123.56	1.26	27.4	34.5
T10	0-30	167.52	122.88	1.24	36.3	45.0
	30-60	168.23	121.85	1.22	38.0	47.3
T11	0-30	161.76	114.42	1.16	41.4	48.0
	30-60	159.46	117.56	1.19	35.8	42.6
T12	0-30	156.43	112.59	1.14	39.2	44.4
	30-60	174.27	125.56	1.28	38.7	49.5

Appendix Table 15: Soil moisture content after irrigation for distribution uniformity of tail field

Sample field	Soil depth(cm)	After irrigation		Bulk Density (g/cm ³)	Moisture After irrigation (θ g %)	Moisture After irrigation (vol %)
		Wet weight (gm)	Dry weight (gm)			
T1	0-30	165.16	115.23	1.17	43.6	50.6
	30-60	170.92	120.82	1.23	41.5	51.0

T2	0-30	153.84	112.72	1.14	36.4	41.5
	30-60	167.76	115.84	1.18	44.8	52.8
T3	0-30	165.87	117.85	1.20	40.7	48.8
	30-60	168.63	119.84	1.22	42.7	51.6
T4	0-30	166.96	113.84	1.16	46.6	54.1
	30-60	169.57	116.45	1.18	45.6	54.1
T5	0-30	160.95	115.53	1.17	39.3	45.9
	30-60	163.76	115.75	1.17	41.4	48.9
T6	0-30	168.62	120.26	1.22	40.2	49.3
	30-60	169.23	115.87	1.18	46.0	54.3
T7	0-30	164.82	110.51	1.12	49.2	55.0
	30-60	173.74	121.52	1.23	42.9	52.8
T8	0-30	172.73	115.84	1.18	49.1	57.9
	30-60	169.55	126.76	1.29	33.7	43.6
T9	0-30	158.63	113.85	1.16	39.3	45.6
	30-60	159.83	116.65	1.19	37.2	44.4
T10	0-30	175.54	120.86	1.23	45.2	55.6
	30-60	169.42	123.86	1.26	36.8	46.4
T11	0-30	162.37	117.16	1.19	38.6	45.9
	30-60	176.23	123.72	1.25	42.4	53.0
T12	0-30	169.62	120.12	1.21	41.2	49.8
	30-60	178.35	127.14	1.29	43.2	55.8

Appendix Table19: Total Moisture stored in root zone of tail field

Sample field	Soil depth (cm)	Moisture before irrigation (Vol %)	Moisture after irrigation (Vol %)	Moisture Stored (Vol %)	Moisture stored in depth(mm)	Total Moisture stored in root zone (mm)
T1	0-30	43.3	50.6	7.3	21.9	36.3
	30-60	46.2	51.0	4.8	14.4	
T2	0-30	31.6	41.5	9.9	29.7	64.2
	30-60	41.3	52.8	11.5	34.5	
T3	0-30	38.3	48.8	10.5	31.5	63.3
	30-60	41.0	51.6	10.6	31.8	
T4	0-30	42.9	54.1	11.2	33.6	49.2
	30-60	48.9	54.2	5.2	15.6	
T5	0-30	37.6	45.9	8.4	25.1	49.7
	30-60	40.7	48.9	8.2	24.6	
T6	0-30	45.9	49.3	3.4	10.2	41.1
	30-60	44	54.3	10.3	30.9	
T7	0-30	46.4	55.0	8.6	25.8	54.9
	30-60	43.1	52.9	9.7	29.1	
T8	0-30	46.8	57.9	11.1	33.3	51.3
	30-60	37.8	43.6	6.0	18.0	
T9	0-30	42.4	45.6	3.5	10.5	40.5
	30-60	34.5	44.4	9.9	29.7	
T10	0-30	45.0	55.6	10.6	31.8	48.6
	30-60	47.3	52.4	5.6	16.8	
T11	0-30	48.0	56.1	8.1	24.3	55.5
	30-60	42.6	53.0	10.4	31.2	
T12	0-30	44.4	49.9	5	15	33.9

	30-60	49.5	55.8	6.3	18.9	
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Appendix Table 16: Total stored water in the root zone

Sample plot	Total stored water at depth of 60cm in the root zone(mm)												
	Head	Sampling point	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11
Moisture stored		52.5	37.9	52.8	45.3	50.1	25.5	43.8	72.6	35	68.7	66.6	34.2
Middle	Sampling point	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
	Moisture stored	45	70.6	84.3	55.2	36.2	75	76.4	88.2	54.9	88.5	38.4	48.7
Tail	Sampling point	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	Moisture stored	36.3	64.2	63.3	49.2	49.7	41.1	54.9	51.3	40.5	48.6	55.5	33.9

Appendix Table 17: Distribution uniformity of the scheme

Sample plot	Mean of lower quarter depth of water stored(mm)	Mean of all water stored(mm)	Distribution Uniformity (%)
Head	33.5	46.1	72.6
Middle	39.9	60.25	66.2
Tail	36.9	49.04	75.2

Appendix Table 18: Deep percolation ratio of the irrigation scheme

Sample plot	Application efficiency (%)	Runoff ratio (%)	Deep percolation ratio (%)
Head	49.3	0	50.7
Middle	51.4	0	48.6
Tail	68.7	0	31.3

Appendix Table23: Cabbage crop water and irrigation water requirement during growing period

Crop: Cabbage			Season: dry season				
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.45	1.54	15.4	1.4	13.0
Nov	2	Init	0.45	1.56	15.6	5.9	9.7
Nov	3	Deve	0.45	1.56	15.6	5.1	10.5
Dec	1	Deve	0.62	2.08	20.7	4.7	16.0
Dec	2	Deve	0.86	2.90	28.9	3.2	25.7
Dec	3	Mid	1.05	3.59	35.9	3.3	32.6
Jan	1	Mid	1.06	3.67	36.7	3.6	32.9
Jan	2	Mid	1.06	3.70	37.0	3.6	33.3
Jan	3	Mid	1.06	3.92	39.2	3.3	38.5
Feb	1	Mid	1.06	3.92	39.2	2.2	37.0
Feb	2	Late	1.04	3.95	39.4	1.5	37.9
Feb	3	Late	0.99	3.79	30.2	4.4	25.84
Mar	1	Late	0.97	3.68	14.7	2.5	11.62
				39.86	360.68	44.8	316.7

Appendix Table24: Carrot crop water and irrigation water requirement during growing period

Crop: Carrot			Season: dry season				
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.5	1.73	10.3	3.5	7.5
Nov	3	Init	0.5	1.74	17.4	5.2	12.2
Dec	1	Init	0.5	1.74	17.4	4.7	12.4
Dec	2	Deve	0.53	1.83	18.3	3.2	15.1
Dec	3	Deve	0.67	2.33	23.3	3.3	22.0
Jan	1	Deve	0.82	2.87	28.7	3.6	25.0
Jan	2	Mid	0.96	3.39	33.9	3.6	30.2
Jan	3	Mid	1	3.63	36.3	3.3	33.0
Feb	1	Mid	1	3.73	37.3	2.2	35.1

Feb	2	Mid	1	3.82	38.2	1.8	36.7
Feb	3	Late	1	3.83	38.3	4.4	33.8
Mar	1	Late	0.96	3.68	36.8	6.3	30.4
Mar	2	Late	0.91	3.52	14.02	3.2	10.02
				37.84	349.2	48.2	299.3

Appendix Table25: Potato crop water and irrigation water requirement during growing period

Crop: Potato			Season: dry season				
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.45	1.54	15.4	7.6	7.8
Nov	2	Init	0.45	1.56	15.6	5.8	9.8
Nov	3	Deve	0.45	1.56	15.6	5.3	10.3
Dec	1	Deve	0.60	2.02	20.22	4.7	15.5
Dec	2	Deve	0.82	2.76	27.6	3.2	24.4
Dec	3	Mid	1.04	3.55	35.5	3.3	32.2
Jan	1	Mid	1.1	3.83	38.3	3.6	34.7
Jan	2	Mid	1.1	3.87	38.7	3.6	35.1
Jan	3	Mid	1.1	3.98	39.8	3.3	40.5
Feb	1	Mid	1.1	4.09	40.9	2.2	38.7
Feb	2	Late	1.09	4.11	41.1	1.5	39.6
Feb	3	Late	1.03	3.89	31.1	4.4	26.7
Mar	1	Late	0.97	3.67	36.7	6.3	30.4
Mar	2	Late	0.92	3.5	14.01	3.2	10.2
				43.8	411.7	57.42	354.75

Appendix Table26: Readily Available Water and irrigation interval required

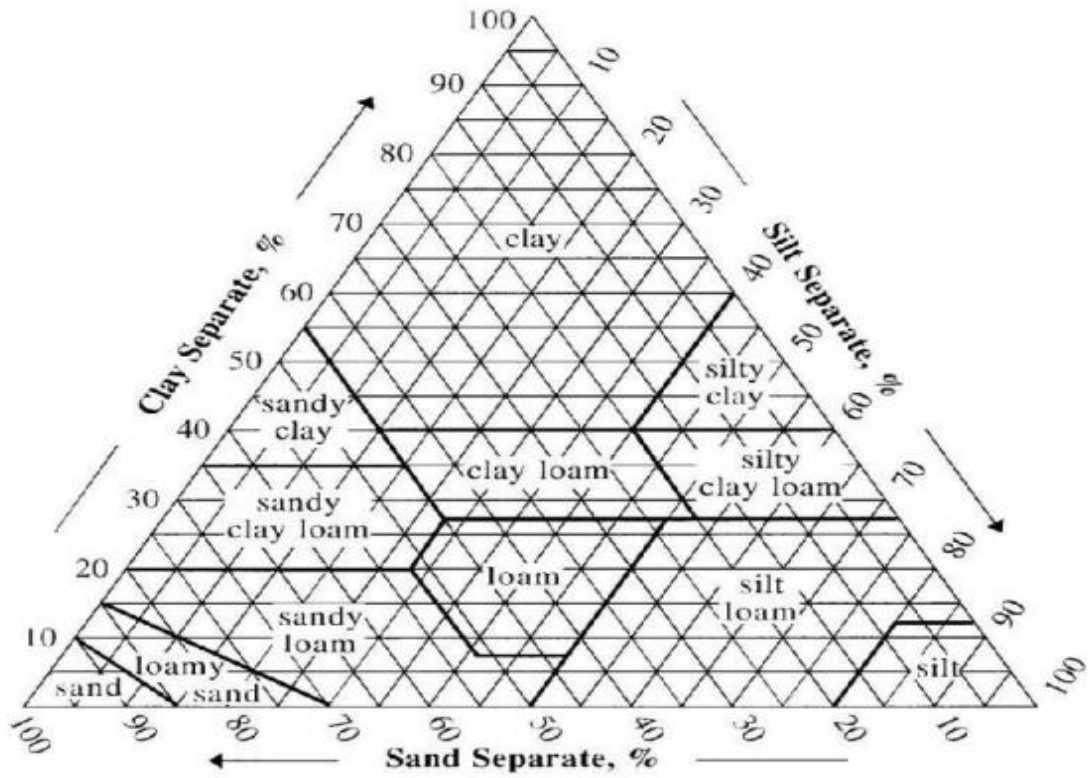
Sample field	Crop type	Soil depth(cm)	TAW (mm)	depletion fraction(P)	RAW (mm)	ETc (mm/day)	Irrigation interval (in days)
Head	Cabbage	60	131.1	0.45	58.99	3.96	15

Middle	Potato	60	65.65	0.35	23.01	4.03	6
Tail	Carrot	60	65.34	0.35	22.86	3.84	6

Appendix Table 27: Crop characteristic data for major irrigated crops in scheme

Crop	Crop parameters	Growth stages				Total	Root depth(m)	Maximum height(m)
		Int	Mid	Dev't	late			
Cabbage	LGP(day)	25	40	35	20	120	0.5-0.8	0.4
	Crop coefficients(kc)	0.7		1.05	0.95			
	Depletion levels(p)	0.45		0.45	0.45			
	Yield response(ky)	0.8	1.1	1	0.6	0.95		
Potato	LGP(day)	25	35	45	15	120	0.4-0.6	0.6
	Crop coefficients(kc)	0.2		1.15	0.75			
	Depletion levels(p)	0.4		0.4	0.4			
	Yield response(ky)	0.4	0.8	1	0.7			
Carrot	LGP(day)	20	30	30	15	100	0.5-1.0	0.3
	Crop coefficients(kc)	0.7		1.05	0.95			
	Depletion levels(p)	0.43		0.35	0.36			
	Yield response(ky)	0.6	0.7	0.9	0.8	1		

Source: (FAO, Irrigation and drainage paper 24(1992) and 56(1998))



Appendix Figure 1: Soil textural class triangle



Appendix Figure2: canal dimension



Appendix Figure3: canal discharge and field discharge measurement



Appendix figure4: materials used and soil analysis in laboratory



Appendix figure 5: materials used for soil sample collection



Appendix figure6: photos during the time of field work.



Appendix figure7: Evident of buried canal segments covered by weeds and soils