PERFORMANCE EVALUATION OF SANKO SMALL SCALE IRRIGATION SCHEME AT BASKETO SPECIAL WOREDA IN SNNPR, ETHIOPIA

MSc THESIS

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PERFORMANCE EVALUATION OF SANKO SMALL SCALE IRRIGATION SCHEME AT BASKETO SPECIAL WOREDA IN SNNPR, ETHIOPIA

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We, the undersigned, members of the Board of Examiners of the final open defense by student **Markos Habtewold Adebo** have read and evaluated his thesis entitled "**Performance Evaluation of Sanko Small Scale Irrigation Scheme**: A Case Study of Basketo Special district, SNNPR, Ethiopia" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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DEDICATION

I dedicate this thesis manuscript to my departed father, HABTEWOLD ADEBO, and my mother TIREZA GURMAMO, for nursing me with affection, love and for their dedicated partnership in the success of my studies.

STATEMENT OF THE AUTHOR

This is to certify that this thesis is my bona fide research work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc. Degree at the Hawassa University Institute of Technology and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that the thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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ABBREVIATIONS AND ACRONYMS

AGPs	Agricultural Growth Program
Av	Cross sectional area of the scheme
Bd	Bulk Density
CROPWAT. 8	Crop Water Requirement Estimation Model Window 8
CSA	Central Statistical Agency
CV	Coefficient of variation
CWR	Crop Water Requirement
GIR	Gross irrigation requirement
NIR	Net irrigation requirement
DAs	Developmental Agents
DPR	Deep percolation ratio
Rz	Root zone depth
E_a	Application Efficiency
E_c	Conveyance Efficiency
E_s	Storage Efficiency
ET_c	Crop Evapotranspiration
ET_o	Reference Evapotranspiration
FAO	Food and Agriculture Organization of United Nation
FC	Field Capacity
FSS	Financial Self Sufficiency
H_1, H_2 and H_3	Fields Selected from Head Water Users
Ha	Hectare
IDD	Irrigation Development Department
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
K_c	Crop Coefficient
LMC	Lower Main Canal
m.a.s.l.	meter above sea level
M_1, M_2 and M_3	Fields Selected from Middle Water Users

MAD	Maximum Allowable Deficit
MoA	Ministry of Agriculture
MoAFS	Ministry of Agriculture and Food Security
MoWR	Ministry of Water Resource
NGOs	None Governmental Organization
P_A	Adequacy indicator
P_D	Dependability indicator
P_E	Equity indicator
P_F	Efficiency indicator
PWP	Permanent Wilting Point
Q	Water Discharge in Canal
Q_D	Delivered discharge
Q_i	Amount of water at inlet point
Q_o	Amount of water at outlet point
Q_R	Required or intended discharge
RAW	Readily Available Water
RR	Runoff Ratio
SNNPR	South Nation Nationalities and Peoples Region
SSI	Small Scale Irrigation
SWCD	Soil and Water Conservation Department
T_1, T_2 and T_3	Fields Selected from Tail End Water Users
TAW	Total Available Water
UMC	Upper Main Canal
V	Velocity of Water in Canal
V_c	Volume of core
W	Width of Canal
W_d	Weight of oven dry soil
W_n	Water Desired to be Stored at the Root Zone
W_w	Weight of Wet Soil
W_Θ	Gravimetric Moisture Content

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ABSTRACT

This study was conducted to evaluate the performance of Sanko small scale irrigation scheme at Basketo Special Woreda, South Nation Nationalities Peoples Regional states. The irrigation scheme includes command area of 120 ha and 600 beneficiaries. To achieve the objective of the study; primary and secondary data were collected. The irrigation scheme was evaluated using minimum sets of internal and external comparative performance indicators which include agricultural, water use, physical and economic performance indicators. In order to evaluate the irrigation water use efficiency of farmers at field level, nine farmer fields were selected from the irrigation scheme in relation to their location (from the head, middle and tail end water users).The internal performance indicators which include conveyance, application, storage, deep percolation ratio and overall irrigation efficiency were used to check the performance of the irrigation scheme. From the analyses of the internal performance indicators, the conveyance efficiencies was found to be 69.3% and application efficiencies were found to be 61.6%, 63.4% and 46.5% at head, middle and tail end part of the irrigation scheme respectively. Average field application efficiency through out of the Sanko irrigation scheme was 57.2%. A deep percolation ratio in the same order of the scheme was found to be 42.8% and Storage efficiencies of 78.5%. Generally overall scheme efficiency of Sanko irrigation scheme was 39.6%. From the evaluation of external comparative indicators, the outputs per cropped area were found as 84,706 Birr ha^{-1}, 220,690 Birr ha^{-1} and 69,686.4 Birr ha^{-1} at head, middle and tail end part of irrigation scheme respectively and the value of the outputs per command area of scheme was 15,003,276 Birr per command area. The output per unit irrigation supply of irrigation scheme was 13.5 Birr m^{-3}, 33.95 Birr m^{-3} and 22.12 Birr m^{-3} at head, middle and tail end part of the scheme respectively. The water use performance of the scheme, like relative water supply and relative irrigation supply were found as 1.28 which was the same since there was no rainfall during study period. The irrigation ratio of the Sanko irrigation scheme was found to be 1.00 which means 100% of command area was under irrigation and additional 25ha was on the construction during study period. Water delivery performance indicator which includes adequacy, efficiency, dependability, and equity from these measures only adequacy was fair and good at head and middle part of irrigation scheme according to standard values but all of other measures were poor according to standard values. In general, based on the evaluation carried out; Sanko irrigation scheme at middle part was performed better than upper head and lower part of the scheme. But there is still a room for improvement of the performance at all of the system level. Therefore to reduce over and under irrigate farmers should get awareness how to use, when to use and how much water used on their fields.

Keywords: Irrigation scheme, performance indicators and irrigation water management

1 INTRODUCTION

1.1 Background

There are mixed perceptions about the contribution of small scale irrigation (SSI) interventions in particular for poverty reduction and food security improvement (Mihret and Ermias , 2014). In Ethiopia, although irrigation has been long practiced at different farm levels, there is no efficient and well managed irrigation water practice (Dessalegn, 1999). The reason could be little efforts made to investigate the irrigated land management and water use in the country. Even some research results have indicated that sometimes no difference is observed between rain fed and SSI user smallholders in their food security status (Peden et al., 2002). However, estimated crop production is not close to fulfill the food requirements of the country (Lambisso, 2005).

Many civilizations have risen on irrigated agriculture. These provide basis for their society and enhance food security of their people (FAO, 1989). Despite the positive contribution of irrigation development for food security and poverty reduction; many irrigation schemes have been unsuccessful and even have had negative impacts (De Fraiture et al., 2009). According to Mohtadullah (1993); Performance can be simply defined as the level of achievement of desired objectives. Awulachew et al. (2010) stated that in many irrigation schemes in Ethiopia issues like water fees, water rights, water conflict resolution, incentives for collaboration between the local, regional, and federal levels of government and incentives for accurate reporting of current projects. Public investment in irrigation in Ethiopia has largely focused on infrastructural development, with very little attention given to operation and maintenance and long-term sustainability issues (Brown 2011; Tilahun et al. 2011; Yami 2013). Even in several modern irrigation schemes in Ethiopia, formal, legitimate and public law of irrigation water users' organizations are generally given less attention and often neglected. Hence, schemes often failed to meet their expectations in terms of sustainability and outputs due to inadequate user involvements and poor institutional setup for proper operation, maintenance and irrigation service provision (Yami and Snyder 2012).

The World Bank, other development banks and numerous countries have invested in large irrigation projects. There have been conflicting opinions about the wisdom of investing further in new irrigation projects, primarily due to the questions about the performance of existing projects (Burt and Styles,1999). There has been an increasing concern about the performance of irrigation systems in recent years. This is due to the fact that many projects have failed to deliver the level of performance expected (Lenton 1988).

According to Small & Svendsen (1992), the evaluation of irrigation performance is clearly important to managers of irrigation projects, but it has been seriously neglected by those who allocate public funds for irrigation and by researchers. In recent years improving irrigation systems; performance is more preferable than developing new irrigation schemes due to investment in small scale irrigation scheme project has failed to produce the expected result in many countries. According to Awulachew et al., (2010) reported that improving low-performing schemes specifically small scale irrigation schemes requires incorporating applied research on irrigated agriculture.

According to Luis (1999) field evaluation play a fundamental role in improving irrigation systems. Performance evaluation result provides the information required for design, model validation and mainly for advising irrigators on how to improve their systems and management practices. Crop production can also be increased through close linking of both inputs of water and nutrients; plant nutrients and water are complementary inputs. Where current crop yields are far below their potential, improvements in soil and nutrient management can generate major gains in water use efficiency (Molden, 2007). Moreover, sustainability is not just the problem of technology and natural resources alone; it is also human, social (institutional and organizational) problem. Adequate institutionalization and organizational development is crucial to enhance management and sustainability of the irrigation systems. Generally IWMI developed two types of indicators to evaluate irrigation systems: internal and external indicators. The aim of applying comparative indicators in this study is to evaluate outputs and impacts of irrigation management practices, interventions across different systems and system levels, as well as to compare various irrigation seasons and technologies with one another while process indicators are used to assess actual irrigation performance relative to system specific management goals and operational target (Kloezen and Garcés-Restrepo, 1998). Evaluating and improving the performance of the existing scheme is an attractive way for sustainable development and used as a bench mark or point of entry for further irrigation development.

1.2 Statement of the Problem

In Ethiopia, scheme performance is estimated on average 36% below design capacity, implying a loss of about 230,000ha of irrigated land, leading to only 410,000ha irrigated. Small scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew et al., 2010). Poor management of available water for irrigation, both at system and farm level has led to a range of problems and further aggravated water availability and has reduced the benefits of irrigation investments (FAO, 1997).The timing of an irrigation event involves utilizing information on crop needs and soil water conditions. Farmers' couldn't obtain enough amount of irrigation water according to their schedule specially in tail end part of the system. As a result, same farmers come to upper and middle parts of the system by finding rental farm lands.

Moreover, losses of irrigation water in the conveyance system can be major component of the overall water losses particularly for farms located at significant distance from diversion points of the main canal. However, the most pressing challenge is the poor water management practice, which is very common in many small scale irrigation schemes. The major cause for such poor performance of irrigation scheme include: poor land preparation and leveling, absence of water level measuring device, poor maintenance of main canal, limited know-how, inadequate practical skills of farmers on crop water needs, soil types and climatic conditions which are instrumental in choosing the more appropriate irrigation methods. Performance evaluation in this study is needed to identify problems in Sanko small scale irrigation scheme from the diversion point to the farmers' field.

1.3 Objective of the Study

The main objective of the study is to evaluate the performance of Sanko small scale irrigation scheme using internal and productivity indicators.

1.3.1 Specific Objectives

- ✓ To determine the efficiency of the surface irrigation system of the scheme
- ✓ To evaluate amount of actual water delivery to the farmers' field and selected crop productivity in the system level
- ✓ To evaluate the on farm water management performance of irrigation scheme
- ✓ To identify and recommend sustainable irrigation water management practice to improve crop production.

1.4 Research Questions

- ✓ What are the main factors which affects the water delivery performances of the irrigation scheme at farm level?
- ✓ Does the quantity of water provided meet the growth needs of the crops planted in a given season?
- ✓ What is the distribution of available water at different location of the irrigation scheme?
- ✓ Does the timing of the water deliveries match the growth needs of the crops and the expectation of farmers?

1.5 Significance of the Study

The study examines water delivery and water use performance indicators at field level in Sanko small scale irrigation scheme. The outcomes of the study provide information on current water use efficiency and compare it with that of designed water use efficiency and thereby contribute to management intervention which could eventually help in achieving the sustainable water use in the area. Since there was few studies about performance of small scale irrigation scheme in Basketo special woreda. The study shall have significant contribution to understand the water distribution in the scheme and limitations of the irrigation system at farm level. It was also give insights the impacts of intervention and directions for water resources managers and also gives an information for further improvement and investment approaches for implementing agents such as AGPs, NGOs, research centers, contractors, etc.

2 LITERATURE REVIEW

2.1 Irrigation Water Control and Management

According to Salman et al. (1999) "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. It is the specific control of all human intervention on surface and subterranean water. 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 U.S Bureau of Reclamation (2005); Irrigation Water Management means management of irrigation water on the farm. 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). 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).

2.1.1 Regulation of flow discharge and water levels

Irrigation scheme flows are controlled with the help of hydraulic structures and water reaches the fields at the proper time and in the quantities needed. To transport water from the source to the fields; an infrastructure 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), the 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) (Low dermilk, 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)..

2.1.2 Irrigation water management

Ahmed (2005) described that water management and control depends largely on proper operation and maintenance of an irrigation development project. It has been seen that without good and efficient operation and maintenance; it is not possible to get desired result. Water management is the integrated process of intake, conveyance, regulation, measurement distribution, application and use of irrigation water at the farmers' field and drainage of excess water from farmers' field with proper amounts and at the right time for the purpose of increasing crop production and water economy in conjunction with other improved agricultural practices. 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. It is widely known that the performance of irrigation systems is below their expectation and potential. 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) described 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. A good management, proper and timely application of water may result in better yield and reduction in drainage problems (Vidhya et al, 2002). Irrigation water management has become a central issue in many countries, in particular after recent studies, which revealed the disappointing performance of many irrigation schemes. Inefficient water use and inadequate water management, both at farm and scheme level mean much less area can be irrigated than planned and agricultural production falls well below target (Mehta, 1994). 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.

Generally, three management levels can be distinguished (Depeweg, 1999):Conveyance or main level by the government or an irrigation authority, Off-farm distribution or tertiary level, by a group of formally or informally organized farmers or water users, e.g. in a water users' organization and field level or on-farm distribution and application system managed by the individual farmer. According to Wil and Vander (1994) managing the operation of an irrigation system is considered a major bottleneck in the improvement of its performance. Managing an irrigation system is not a simple task. Many different parties are involved; each with their own interests, however information on irrigation water management in a detailed scale like at country level is not common due to the lack of data, reliability and accessibility of the data (Merdun and DeIrmenci, 2004).

2.2 Performance Evaluation of Irrigation Practices

2.2.1 Purpose of irrigation performance evaluation

Kloezen and Graces (1998) stated that effective irrigation management requires reliable performance evaluation. Good farm irrigation management assures correct frequency of irrigations, correct application depth, uniform irrigation, minimum runoff, and minimum deep percolation except for that required for salt management, minimum erosion, and optimal return on irrigation investment. According to FAO (1989) the principal objective of evaluating surface irrigation systems is to identify management practices and system configurations that can be feasibly and effectively implemented to improve the irrigation efficiency. An evaluation may show that higher efficiencies are possible by reducing the duration of the inflow to an interval required to apply the depth that would refill the root zone soil moisture deficit. The evaluation may also show opportunities for improving performance through changes in the field size and topography. The surface irrigation system is a complex and dynamic hydrologic system and thus, the evaluation processes are important to optimize the use of water resources in this system (Walker, 1989).

The performance of an irrigation system is represented by its measured levels of achievement in terms of one or several parameters that are chosen as indicators of the system's goals (Style and Marino, 2002). The cause of the poor irrigation performance has been blamed on technical, financial, managerial, social, and institutional causes. As Prasad and Jayakumar (2003) indicated performance assessment practices are very much essential because of their central role in effective management. Dawit et al. (1997) defined performance as a measure of "how close an irrigation event is to the reference irrigation. Performance evaluation in irrigation can be defined as the systematic observation, documentation and interpretation of activities related to irrigated agriculture with the objective of continuous improvement. Performance assessment is an activity that supports the planning and implementation process. The ultimate purpose of performance assessment is to achieve an efficient and effective use of resources by providing relevant feedback to the project management at all levels (Molden et al., 2004). Schultz and De Wrachien (2002) described that the aim of performance assessment is to select a small number of powerful, easily observable indicators that allow reliable conclusions to be drawn. The performance assessment should be a regular, short duration process for investigating suspected critical shortfalls in performance. According to Bos (2000) the wider objectives of performance assessment is to upgrade management capabilities in both public and private sector irrigation and drainage projects with a view to improving the efficiency with which available resources are used. As such, the assessment should become part of the routine management procedures of the irrigation institution.

Small and Svendsen (1992) identified four different interrelated purposes of performance assessment: operational, accountability, intervention and sustainability. Operational performance assessment relates to the day to day, season to season monitoring and evaluation of system or scheme performance. Accountability performance assessment is carried out to assess the performance of those responsible for managing a system or scheme. Intervention assessment is carried out to study the performance of the scheme or system and generally, to look for ways to enhance that performance. Performance assessment associated with sustainability looks at the longer-term resource use and scheme or system impacts. Yashima (1997) described that the responsibilities of irrigation managers in irrigation performance evaluation encompass (1) evaluating the existing situation of irrigation performance in their systems, (2) identifying constraints to proper performance if the performance is not satisfactory, and (3) implementing management interventions to improve the performance. At all levels, performance must be evaluated using a combination of targets and associated set of standards that describe the acceptable range of values around that target (Bos et al., 1994).

2.2.2 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 of quantity and be accompanied by appropriate standards or permissible tolerances (Rust and Snellen, 1993). The improvement of irrigation practice requires knowledge of crop water requirement and yield responses to water, the constraints that are specific to each irrigation method and irrigation equipment, the limitation to water supply system and the financial and economic implication of irrigation practice. Improvement of irrigation method requires the considerations of the factors influencing the hydraulic process, the water infiltration and uniformity of water application to the entire field (Hlavek, 1992). Performance evaluation exercises are meaningful if related with certain management objectives that are defined for certain given situation. Some key indices or terms are developed that are used to describe the achievement of these objectives, followed by the identification of variables that are controllable and measurable and can be regulated to achieve the established indicators. The indices are used to evaluate the farm irrigation system that could be categorized into delivery subsystem (the system extending from head works to field canals), and water use subsystem (part of the system extending from field canals to water application system).

The indices should be subjected to management control so that they can be manipulated to improve system performance (Walker and Skogerobe, 1987). Efforts have been made over the years to develop appropriate evaluation models that could use the irrigation parameters and variables to evaluate irrigation performance. Among these, the volume balance model is the basis for most design and field evaluation procedures. This has been proven with field and laboratory data. In addition, few of these criteria reflect the view of the farmers (Gowing et al, 1996). It is therefore essential that evaluation of the performance of surface irrigation systems be continued with a view to improve the performance of the systems and also to incorporate the view of the stake holders, i.e. the farmers in particular. Different indices have been developed that are used for evaluating the performances of individual irrigation systems and for comparing the performances of different irrigation systems as well as farms. The type and number of indices (indicators) used for a particular situation depend on the level of details required for quantification, and on the number of disciplines selected for assessment. These may include, Agricultural, water use, economics, environment, management, physical etc. which are regarded as external indicators (Bos, 1997).The common efficiency terms used for on-farm irrigation system evaluation (internal process indicators) include application efficiency, storage efficiency and adequacy, and recently complementary terms such as runoff ratio, deep percolation ratio, are being applied (Jureims et al, 2001). The principal terms and their uses are described as follows.

2.2.3 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. Analysis of the field data allows quantitative definition of the irrigation system performance. The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field (Feyen and Dawit, 1999).

2.2.3.1 Conveyance Efficiency

Significant volume of water is lost by the networks of the conveyance canals due to seepage and evaporation depending on the nature of the soil and agro-climatic zone in which the canals are located. 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. 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 (Rust and Snellen, 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 (Bos, 1997). 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, and maintenance, and the nature of the soil that affects the seepage rate. However, typical conveyance efficiency values generally reported are 70 and 50% for unlined poorly managed main and field canals respectively, while for the well managed canals the figures were 85 and 80% respectively (MoAFS, 2002). Conveyance efficiency (Ec), for lined canal this is assumed at 0.9, but for unlined could be down to 0.7 (Halcrow et al. 1992).

2.2.3.2 Application Efficiency

The Application Efficiency is a term initially formulated by Israelson (1950) and measures the ratio between the volumes (depth) of water stored in the root zone for use by the plant to the volume (depth) of water applied to the field. As reported by Walter and Berisavijevic (1991) the term has been expressed in different ways over the years to include different parameters by different authorities. Field irrigation efficiencies are influenced by factors such as soil type, field application methods, depth of application and climate. Very high values are achieved in arid climates and where water shortages prevail. However in the area where the water applied exceeds water required, indicating an over irrigation, emphases should be given to reduce the amount of irrigation water (Walters and Berisavijevic, 1991). Field application efficiency (Ea), for conventional furrow ranges from 45−65% (Irmak et.al, 2011).

2.2.3.3 Deep percolation Ratio

A component of the irrigation applied to a field percolates into the soil below the root zone. Part of the water is intentionally added to the irrigation water to maintain the salt balance of the soil through leaching additional salt brought by the irrigation water itself or through capillary process from saline ground water (Smedema and Rycroft, 1983). The volume of percolated water in excess of the leaching requirement is considered as lost water and is used to define the efficiency of irrigation. 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).

2.2.3.4 Storage Efficiency

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. The value of E_s is important either when the irrigations tend to leave major portions of the field under-irrigated or where under irrigation is purposely practiced to use precipitation as it occurs. This parameter is the most directly related to the crop yield since it was reflect the degree of soil moisture stress. Usually, under-irrigation in high probability rainfall areas is a good practice to conserve water but the degree of under irrigation is a difficult question to answer at the farm level (Walker, 1989).

2.2.3.5 Overall scheme efficiency

Irrigation efficiencies are evaluated at scheme or 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. As reported by the MoAFS (2002) for small irrigation schemes in Tanzania typical values proposed were 28 and 34% for poorly operated and for well operated canals, respectively. In addition to design and other technical factors, the farm efficiency is much regulated by the operation of the main supply system to meet the actual field supply requirements and the skill of the system operators (FAO, 1977). System efficiency (E_p), this is assumed to be 0.6 (Merwe 1997, Halcrow et al. 1992).

2.2.4 Productivity Performance Indicators

Many indicators used for external performance evaluation can be calculated from secondary data rather than primary data. These set of indicators are designed to show gross relationship and trends and are useful in indicating where more detailed study should take place, where a project has done extremely well, or where dramatic changes take place. According to Bos et al. (1994) external performance indicators are grouped in the following section:

2.2.4.1 Irrigated Agriculture Performance Indicators

They are used for the evaluation of the project performance in terms of the production it results in. It expresses output of irrigated area in terms of gross or net value of production measured at local prices. This addresses the direct impact of operational inputs in terms of such aspects as area actually irrigated and crop production, over which an irrigation manager may have some but not full responsibility.

2.2.4.2 Water use performance indicators

This deals with the primary task of irrigation managers in the capture, allocation and conveyance of water from source to field by management of irrigation facilities. Indicators address several aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently and the service aspects of water delivery which include such concepts as predictability and equity.

2.2.4.3 Physical Performance Indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. Among those reason water scarcity and input availability are the main reason why lands in command area are not fully under irrigation in a particular season. From physical performance; irrigation ratio and water delivery ratio are the two main indicators.

2.2.4.4 Economic Performance Indicators

This indicator considers the production and the total cost of infrastructure for scheme. It deals with the total revenues from the scheme, total cost spent for running the project and initial investment costs. Economic indicators deal with how much investment cost is spent on the project in comparison with total production and how much fee collected from water users' for yearly maintenance and operation expenditure and whether the system is self-sufficient or not (Vermillion, 2000).

2.3 Previous Work on Irrigation Performance

2.3.1 Global experience

Rapid increases in world's population have made the efficient use of irrigation water vitally important, particularly in poorer countries, where greatest potential for increasing food production and rural incomes is often to be found in irrigated areas. It has therefore become a matter of series concern in recent years that, their very high costs, the performance of many irrigation schemes has fallen far short of expectation (FAO, 1986).

2.3.2 Previous Irrigation Performance in Ethiopia

Small scale irrigation development was previously carried out by the surface water division of the Soil and Water Conservation Department (SWCD) of the Ministry of Agriculture (MoA). In 1984 the division was separated from SWCD and upgraded to the Irrigation Development Department (IDD). In 1987, the activities of MoA were being decentralized to zonal offices and IDD staff was being transferred to strengthen the capacity of the zones. However, in 1992 a new Ministry of Natural Resources Development and Environmental Protection (MNRDEP) was created, with responsibility for soil and water conservation, rural water supply and sanitation.

Although the MoA retained responsibility for providing agricultural support services, the IDD was dissolved and its responsibilities were transferred to regional Natural Resources Bureau. In August 1995, MNRDEP was dissolved and its responsibilities were shared between MoA and the Ministry of Water Resources (MoWR). Under the new arrangements, responsibility for irrigation development belonged to the Bureau of Water, Minerals, and Energy Resources Development (BWMERD) while MoWR has an overall policy, planning and regulatory role in respect of water resources development.

2.4 Water delivery system performance Indicators

The success of an irrigation water delivery system can be measured by how well it meets the objectives of delivering an adequate and dependable supply of water in an equitable, efficient manner to users served by the system. If water does not arrive at farms in an adequate and timely amount, crop yields may suffer and farm net returns may decrease.

Also, it is important that each farmer receives a fair, while not excessive, amount of water. Performance measures should be functions of state variables that have a direct impact on the fulfillment of system objectives, should be intuitively easy to interpret, and should be relatively easy to measure or predict (Molden and Gates 1990). The major state variables that determine water delivery system performance may be defined in terms of an amount of water Q, which may refer to rate, volume, frequency, or duration of water delivery.

The water delivery service performance measures deal with issues of adequacy, equity, and reliability. These are the type of issues addressed with these performance parameters (Clemmens and Molden 2007). In this research four indicators proposed by Molden and Gates (1990) and subsequently applied by Unal et al (2004), Shahrokhnia and Javan (2005), Vandersypen et al (2006), were used to assess the water distribution system namely adequacy, efficiency, dependability and equity which are performance objectives considered when evaluating irrigation water delivery.

2.4.1 Adequacy

Adequacy deals with water supply to the crop relative to its demand. The measure of adequacy, relative water supply (RWS), proposed by Levine (1982) is the most comprehensive. RWS is the ratio of supply due to irrigation and effective rainfall to the demand due to evapotranspiration and other needs. This indicator in itself or in little modified form (to account for variation in supply and demand) was used or proposed by many (Keller, 1986; Moya and Walter, 1988; Oad and Padmore, 1988; Weller, 1991; Sakthivadivel et al, 1993 and Bos et al 1994).

2.4.2 Equity

Some authors (Abernethy, 1986 and Khepar et al, 2000) have argued that the equitable distribution of water is also necessary for maximizing productivity. They argue that the farmers at the head of the system generally apply more water than needed for potential yield and excess water would not improve the productivity but could reduce it. If instead the excess water were diverted to another part of the scheme receiving less water than needed to produce potential yields, then the production would have increased. However we feel that when water is scarce and managed optimally, the productivity and equity become conflicting issues, as observed by Gorantiwar (1995) and Kalu et al, (1995).

2.4.3 Reliability

Abernethy (1986) defined reliability as deliveries according to some schedule and according to him, unreliable water supplies are undesirable to a system’s overall health. The successful results of the allocation plans depend on reliable supply. The maximum reliability of water supply is often more important than maximum adequacy. The farmers may be happier with a water delivery system in the irrigation scheme that delivers an inadequate supply which is reliable, than with the adequate supply which is not reliable. If the farmers are sure that the deliveries are according to the schedule communicated to them, they can plan their activities accordingly resulting in higher productivity.

2.4.4 Efficiency

Efficiency embodies the ability to conserve water by matching irrigation application with crop water requirements. Allocation plans are developed using estimated efficiencies of water flow at various stages and time and if these allocation plans are implemented properly, most of the performance measures described above will be good indicators irrespective of whether the efficiency of the network is good or bad. However deteriorating efficiency over the years will reduce the performance of the irrigation schemes over this period. Hence though the efficiency is related to the maintenance of the physical infrastructure of the water distribution network it needs to be evaluated as performance of the irrigation scheme when it is in actual operation. This helps to show the causes of performance deviating from the desired standard (Bos et al 1994 and Bos, 1997).

2.5 Economic Analysis of Irrigation Scheme Performance

The productivity is related to output from the system in response to the input added to the system and there are several indicators of productivity. The principle output of the scheme is the crop produce or its economic equivalence and the area irrigated. These need to be assessed seasonally or annually. The productivity can be indicated by measuring these outputs in gross terms or relative to input utilized. The inputs of interest in irrigation are land, water and finance. The productivity is relevant when the outputs are measured in terms of whichever input is scarce. Lenton (1986), Chambers (1988), Abernethy (1989), Steiner (1991), Burton (1992) and Hales (1994) listed various indicators of productivity. All these can be summarized as total production; total net benefits and total area irrigated in gross terms, and total production or benefits or area irrigated per unit of water utilized or area available or under crop. The water utilized is measured at various levels in the irrigation scheme i.e. from the head works to the root zone of the crop.

3 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location and Topography

The Basketo special woreda is found in Gamo-Gofa zone of SNNPR which is 310 km, 460 km and 626 km from Arba-Minch, Hawassa and Addis Ababa respectively. It is located geographically at latitude of 6°5′ 0″ to 6°25′ 0″N and longitude of 36°25′ 0″ to 36°40′0″E (Figure 3.1). Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), the woreda has a total population of 56,689, of whom 28,532 are men and 28,157 are women. Basketo district is endowed with many rivers that are potentially good for small scale irrigation. However, undulating and rugged topography of the area made the rivers were hardly accessible for surface irrigation. In some of the small scale irrigation schemes, problems linked with design of canals that bring water from the source (rivers) are lowering their performance and coverage of the system. Sanko small scale irrigation scheme was constructed by regional water and irrigation development bureau in year 2002 E.C and which is 18 km far from the main road of the district. Command area covered by the scheme was 120 ha with total of 600 households of irrigation users' (350 males and 250 females). Sanko small scale irrigation scheme was geographically found at 36.55°E longitude and 6.26°N latitude. The elevation variation of the catchment upstream of the irrigation diversion point ranges from 813 − 894 m a.s.l. while, the woreda ranges from 780 − 2200 m.a.s.l.

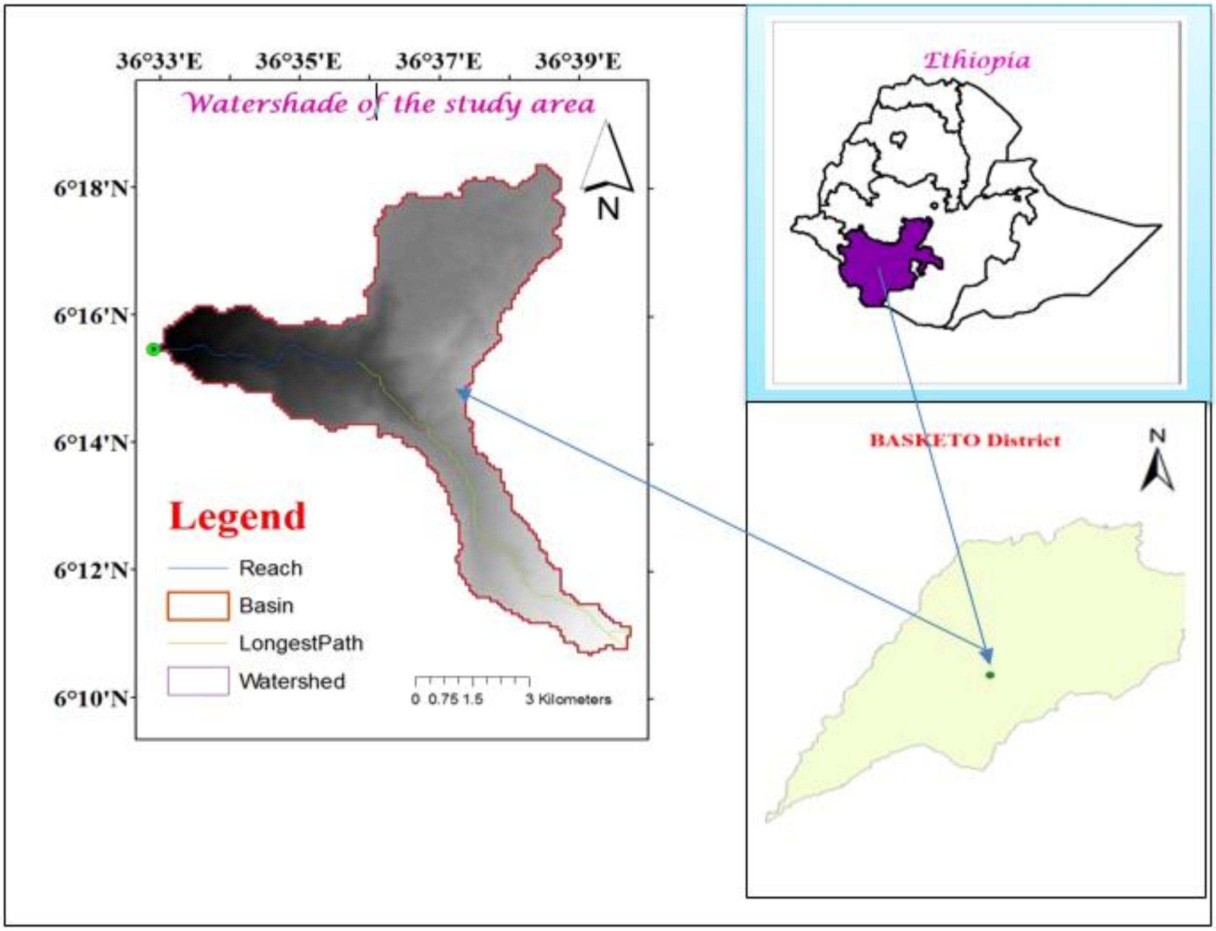

Figure 3.1. Location map of the study area

3.1.2 Climate

Climate is a long period average weather condition of a defined geographical area. It is determined by altitude, latitude, prevailing winds, cloud cover, pressure and wind belts. Altitude is by far determinant factor for the spatial variation of weather and climate. Among the elements of weather and Climate, temperature and rainfall are important elements in determining the pattern of population settlement, the range of crops and vegetation that can be grown, soil formation processes and biodiversity and agro ecology of a given area. The Climatic condition of the project area is very hot and there is nearby meteorological stations Bulki, Felege-Neway and Jinka were used to get average climatic data of the study area. The project area is characterized by kola agro-climatic zone with shrubs and bushy vegetable types. The average annual rain fall of the Woreda is 1500.5 mm (minimum 1401mm and maximum 1600 mm) with minimum and maximum temperature of 17.6°C and 27.5°C respectively (JICA, 2012).

3.1.3 Land use pattern

The land use pattern of the district area is found to be combination of grass land, forest land, water body and woody land. The total land coverage of the woreda is 105,750.75 ha of which 19,250 ha is covered by annual and perennial crops, 2,250 ha grazing land, 491.75 ha forest land, 103 ha water body, 566 ha bare land and 83,090 ha others (Solomon et al., 2018).

3.1.4 Soil

The soil's moisture holding capacity, intake rate and depth are the principal criteria affecting the type of system selected. Sandy soils typically have high intake rates and low soil moisture storage capacities and may require an entirely different irrigation strategy than the deep clay soil with low infiltration rates but high moisture-storage capacities. Sandy soil requires more frequent, smaller applications of water whereas clay soils can be irrigated less frequently and to a larger depth. The soils of the woreda classified as 18 % clay, 52 % clay loam and 30 % sandy in all agro ecologies such as highland, midland and lowland (Solomon et al., 2018)..

3.3 Data collection

The study was carried out starting from November to March; 2017/18 of the irrigation season. In this study; primary and secondary data have been gathered and engaged for the study purpose. For field data collection and measurement purposes; auger for soil sample taking, Core sampler auger for bulk density, Measuring tape for measure of the field sizes and flow distances for surface velocity calculation in the main canal, Sensitive weighing balance for measure of fresh and dry weight of the soil, Cans, for putting soil in to oven dry, Pressure palate for determining, field capacity(FC) and permanent wilting point(PWP) of the soil, Stop watch for time recording of floating materials and time of application of irrigation water to the field, Floating material for measuring flow velocity and three inch parshall flume with dimensions 14 feet long, 12 inches deep and 10 inches wide for measuring amount of water applied to the field.(Kandiah, 1981).

3.3.1 Primary data collection

Frequent field observations were made to observe and investigate the method of water applications and practices related to water management techniques made by the farmers. Measurements of flow velocity, canal cross sectional area and discharge at different points of irrigation scheme was taken. To determine soil texture of field, soil samples from the three selected locations based on distance from main canal of the scheme at three different depths based on maximum root zone of the selected crop onion was collected. And also using core sampler auger; undisturbed soil samples was collected from different depths and the bulk densities at different depths were determined. Soil samples were also collected to determine the soil moisture content one day before and after irrigation by collecting about nine soil samples from the scheme with an interval of 20 cm up to maximum root depths of the selected crop Onion. The Onion was the only short season crop widely practiced in Sanko irrigation scheme during study period rather other perennial crops like banana, sugarcane, papaya, orange and lemon. Type of crop, effective root depth, total growing period, crop coefficient and maximum allowable depletion fraction were collected. It is presumed that the effective root zone of the irrigated vegetable crop onion is not more than 60 cm depth (Allen et al., 1998).

3.3.2 Secondary data collection

For the selected Sanko small scale irrigation scheme, secondary data levels like climatic data, investment cost, fees from irrigation users', total irrigation users in the command area, operation and maintenance costs were collected from the Basketo woreda of Agricultural and Rural Development office, Water Resource and Irrigation office at regional and zonal levels. Average climatic data of the study area was collected from the nearby metrological stations such as, Bulki, Felege- Neway and Jinka meteorological stations.

3.4 Determination of Crop Water and Irrigation Water Requirement

Crop water requirements (CWR) refer to the amount of water required to compensate for evapotranspiration losses from a cropped field during a specified period of time and irrigation water requirement refers to the amount of water, in addition to rainfall, that must be applied to meet a crop's evapotranspiration needs without significant reduction in yield. Crop water requirements are expressed usually in mm/day, mm/month, or mm/season. CROPWAT 8.0 computer program was used to estimate the total water requirements of onion crop in the irrigation scheme. FAO (1992) Penman-Monteith method was selected to calculate the reference crop evaporation (ET_o).The model needs climatic, crop and soil data for the determination of crop water and irrigation requirements. To determine ETo values the model requires climatic data; mean monthly minimum and maximum temperature (^{0}C), relative humidity (%), wind speed (km/day) and sunshine hours (hr). The program estimates (ETc) based on equation:-

$$ETc = (ETo * Kc) ---------------------------------(1)$$

Where:

ET_c is actual evapo-transpiration of crops (mm)

ET_o is reference evapo-transpiration (mm)

K_c is the crop coefficient (dimensionless)

3.5 Soil Data Analysis

Soil samples were collected from the field to analyze its selected physical properties. The soil physical properties to be analyzed include soil texture, bulk density and soil moisture contents at field capacity and permanent wilting point. Bulk density was determined using the core method (Blake, 1965). Water contents at field capacity at 0.33 bar and permanent wilting point at 15 bar was determined in Ethiopian Construction and Supervision Works Corporation; Research Laboratory and Training Center using the pressure plate apparatus (Grewal et al,.1990).

3.5.1 Soil Texture

Soil texture is the amount of sand, silt and clay in the soil. It has a strong influence on water storage and availability because of the variation in the particle size distribution and the surface area. Smaller particles fit together more tightly than larger particles and therefore the pores for air and water are also smaller. Small pores retain water against gravitational forces, drainage and also against plant use, while the larger pores found in sand allow water to drain. Ideally, a soil was contain a range of pore sizes, larger pores which drain readily so as to prevent water logging following soil saturation and smaller pores which store water for plant use. Not all water held in very small pores is available to plants because water can be retained strongly (IMG, 2010). The textural triangle diagram was used to identify the proportion of sand, silt and clay percentages(Appendix figure 1).

3.5.2 Bulk density of the soil

Bulk density refers to the soil overall density or compactness of a soil and should be distinguished from the soil density of the solid soil constituents, usually called the particle density. The bulk density is affected by structure of the soil, i.e., its looseness or degree of compaction, as well as by its swelling and shrinkage characteristics, which are dependent upon clay content and wetness. The bulk density is also the ratio of oven-dried mass of a soil to its volume for undisturbed soil condition and is expressed on dry weight basis of the soil as (Blake, 1965):-

$$B_d = \frac{M_d}{V_c} \text{ ------------------------------------ } (2)$$

Where Bd is the soil bulk-density (gm cm^{-3})

Md is the weight of oven dried soil (gm)

Vc is the volume of core (cm ^{3})

3.5.3 Moisture Content of Soil

The moisture content of the collected soil samples were determined using gravimetric method. In this method soil samples were taken with soil auger and weighed and dried in an oven at 105 ^{o}C for about 24 hours, until all the moisture is driven off. After removing from oven they were cooled slowly at room temperature and weighed again. The difference in weight is the amount of moisture in the soil (Michael, 1978).

$$W_{\theta} = \left(\frac{W_w - W_d}{W_d} * B_d * 100\right) ---------------------------(3)$$

Where

W_{θ} is gravimetric soil moisture content (% volume bases)

W_w is wet weight of the soil (g)

W_d is dry weight of the soil (g)

B_d is bulk density of soil (g cm^{-3})

3.5.4 Total Available soil Water

Grewal et al. (1990) observed that knowledge of the soil water content at field capacity (FC) and permanent wilting point (PWP) is important for irrigation scheduling, assessing plant water requirement and soil suitability for different land uses. Studies by Salter and Williams (1980) provided a framework for estimating field capacity and permanent wilting point. The total Available Soil Water (TAW) was computed from the soil moisture content at Field Capacity (FC) and Permanent Wilting Point (PWP) using expression:

$$TAW = \left(\frac{FC - PWP}{100}\right) * B_d \ * Rz ---------------------------(4)$$

Where TAW is total available water (mm), FC and PWP in % on weight basis, Bd is the bulk density of the soil in gm cm^{-3} and Rz is the maximum effective root zone depth in mm

3.5.5 Readily Available Water

It is the portion of the total available water (FC – PWP) which is most easily extracted by the plant roots without creating stress. The water content near to PWP cannot be easily extracted by the plant roots. Therefore, only part of the TAW is used before the next irrigation. The term

Maximum or Management Allowable Deficiency, (MAD) can be used to compute the amount of water that can be used without adversely affecting the plants and can be expressed as a fraction of the TAW. This value varies with the crop type and could be obtained experimentally. Once the MAD is known, it is possible to compute the net irrigation water requirement, IR_n, necessary to restore the main root zone, to FC. Readily available water can be expressed in equation given in equation (5).

$$\mathrm{RAW} = (\mathrm{TAW} * \mathrm{P}) \text{ -------------------------------- } \quad (5)$$

Where

RAW is readily available water

P is in fraction for allowable soil moisture depletion for no stress

3.5.6 Irrigation Scheduling

For determination of irrigation schedule of the irrigation scheme and to make comparison with the current irrigation practices; moisture content, field capacity, permanent wilting point, depletion fraction at each growing stage data were collected. Additionally farmer's irrigation practices were determined; such as irrigation methods, irrigation frequency and interval of irrigation, and application depths. During the determination of the amount of water applied to the field, the average water flow rate to the farm inlet and respective time were recorded with the size of the fields being irrigated. The total volume of water applied to the field was obtained by multiplying the discharge rate with the inflow time. The depth of water applied to the field was obtained by dividing the total volume of water applied to the area irrigated. Considering the daily CWR, TAW, Dz, Bd and p, the irrigation interval could be computed from the expression(Rao et al. 1992):-

$$\mathrm{Interval(days)} = \frac{\mathrm{RAW}}{\mathrm{CWR}} \text{ -------------------------------- } \quad (6)$$

3.6 Performance Evaluation Methods

Performance of the scheme was evaluated using both internal and productivity performance indicators. The internal performance indicators were conveyance efficiency, application efficiency, storage efficiency, deep percolation ratio and overall scheme efficiency. For computation of absolute performance efficiencies, irrigation fields with onion crop were selected. A total of nine locations were selected based on distance apart from the irrigation scheme, i.e. three from the head (H_1, H_2, and H_3); three from the middle (M_1, M_2, and M_3) and three from the tail (T_1, T_2 and T_3) end water users of irrigation scheme which was represent appropriate sampling of study (Eticha, 2011 and Yesuf, 2003). The standardized performance indicators established by IWMI was taken to measure external indicators. The external indicators included in this study were agriculture, water use, physical and economic performance indicators (Molden et al., 1998).

3.7 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 (Yesuf,2004).

3.7.1 Conveyance Efficiency

Velocity of the flow was calculated to determine amount of water loss in the scheme using floating method. Floats are a simple way of measuring the velocity of a stream, but they are not very accurate. The surface velocity is obtained by measuring the time (t in sec) for a float to travel a measured distance (L in meters). It is best to choose a straight, uniform canal section about 30m long canal length was taken for this study and to time the float over a ten number of repeated t runs was taken in each of upper and lower main canal. A piece of citrus fruit lemon makes a good float, as it is less affected by wind than a wooden sticks. A reduction factor of about 0.85 should be used to convert surface velocity to average velocity (Tigabu, 2017).

$$\text{Surface velocity}\left(\frac{m}{s}\right) = \left(\frac{L}{t}\right) \quad (7)$$

$$\text{Average velocity}\left(\frac{m}{s}\right) = \left(\frac{0.85 * L}{t}\right) \quad (8)$$

The cross section of the canal was measured up carefully in a number of places along the test distance and the average cross-sectional area calculated (A sq m). Geometry of the Sanko irrigation canal is rectangular; so cross sectional area was calculated as (Garg, 2005):

$$A = (b * y) \quad (9)$$

Where

b is base width of canal

y is water depth in the canal

Discharge can be calculated by multiplying average velocity and cross sectional area of the irrigation canal as (Tigabu, 2017).

$$Q\left(\frac{m^3}{s}\right) = \left(\frac{0.85 * L * A}{t}\right) ------------------------------ (10)$$

Conveyance efficiency is the ratio of water delivered in to the field from outlet point of the canal (Q_o) to water entering in to the canal at it staring point (Q_i). Accordingly, the conveyance efficiency of the canal was computed by taking discharges measurement at different points. The measurements also were taken throughout study period at initial and final points of main (Ramulu, 1998). The conveyance efficiency of the scheme was also computed as:-

$$E_c = \frac{Q_o}{Q_i} * 100 ---------------------------- (11)$$

Where E_c is conveyance efficiency (%)

Q_i is depth of water diverted from the source (m^3)

Q_o is depth of water applied to the field (m^3).

3.7.2 Application Efficiency

The application efficiency was computed as the ratio of quantity of water stored in to the root zone of crops (NIR) to the quantity of water actually delivered in to the field (GIR). In this particular research soil samples were collected from different selected fields of the scheme at depths of 20cm interval based on maximum root depth of the selected onion crop and the amount of water stored in the root zone determined by gravimetric method. Application efficiency was computed as follows (Ramulu, 1998):

$$Ea = \frac{NIR}{GIR} * 100 ------------------------------ (12)$$

Where

E_a is application efficiency (%),

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

GIR is average depth of water applied to the field (mm).

The amount of water applied through parshall flume to a field is a function of time, flow and area. The time of irrigation is easily recorded. The amount of area irrigated is also easily calculated. However, estimating flow rate in an open ditch of parshall flume by equation given by (Kandiah, 1981).

$$t = \frac{A * GIR}{6Q} ------------------------------------ (13)$$

Where

t is time of application (min)

A is area of the plot (m^2)

GIR is amount of water applied to the field (cm)

Q is flow rate or discharge (l/s)

3.7.3 Deep Percolation Ratio

The runoff ratio was normally being considered for this particular study as zero as the farmers' are using furrows whose tail ends are closed. However, the deep percolation ratio was computed as the ratio of the percolated water beyond the root zone to the volume of water applied to the field. It was computed using the following formula (Feyen and Dawit, 1999):

$$DPR = (100 - Ea - RR) ----------------------------- (14)$$

Where

DPR is deep percolation ratio (%)

E_a is application efficiency and

RR is runoff ratio.

3.7.4 Storage Efficiency

The 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. Based on the moisture content at field capacity, permanent wilting point and bulk density of the soils of the selected irrigation fields and the root depth of the crop irrigated; the depth of irrigation water required by the onion crop was calculated at the 25% moisture depletion level (Allen et al., 1998). After determining the storage and the required depths; the storage efficiency was calculated using the following formula (Ramulu, 1998)

$$Es = \frac{NIR}{Wn} * 100 ------------------------------ (15)$$

Where:

E_s is storage efficiency (%),

NIR is water stored in the root zone (mm)

W_n is water desired to be stored in the root zone (mm).

3.7.5 Overall Scheme Efficiency

Irrigation efficiencies are evaluated at scheme or farm level for the purpose of identifying the losses that occur in the irrigation system starting at the water abstraction point from the sources, through the conveyance system down to water application in the field, to determine the overall irrigation efficiency. As reported by the MoAFS (2002) for small irrigation schemes in Tanzania typical values of overall scheme efficiency proposed were 28 and 34% for poorly operated and for well operated canals, respectively. In addition to design and other technical factors, the farm efficiency is much regulated by the operation of the main supply system to meet the actual field supply requirements and the skill of the system operators (FAO, 1977). Finally the overall scheme efficiency was calculated as the product of conveyance and application efficiency. It was computed using following formula (Ramulu, 1998):

$$E_p = (E_c * E_a) \text{ --------------------------------- } (17)$$

Where

E_p is overall scheme efficiency (%)

E_c is conveyance efficiency (%) and

E_a is application efficiency (%).

3.8 Productivity Performance Indicators

The external performance of the scheme was evaluated using some selected comparative indicators, which are normally classified into four groups, namely agricultural, water use, physical and economical performances' as standardized by IWMI (Molden et al., 1998). To compute the total production of scheme in selected crop onion grown in the respective sites, average yield per ha as well as an average price for the crop per kg was collected for scheme. The design feasibility study documents of the irrigation projects was collected from the Regional irrigation and water resource Bureau for Sanko irrigation project and was used as a source of information on the operation and maintenance costs of the irrigation projects. The results obtained on all the indicators were used to evaluate the performance of the scheme. For the evaluation of irrigated agriculture performance, four indicators related to the output of different units were used. They are used for the evaluation of the project performance in terms of the production it results in. The selected indicators used to evaluate irrigated agriculture performance are output per cropped area (Birr ha^{-1}), output per command area (Birr ha^{-1}), output per irrigation supply (Birr m^{-3}), Output per water consumed (Birr m^{-3}) as the ratio of production in Birr per volume of water consumed (m^3) (Molden et al., 1998).

3.8.1 Agricultural Performance Indicators

Output per unit irrigated area (Birr/ha)

It was computed as the total value of production per harvested area in the irrigation season. The harvested /irrigated / area includes the areas that were irrigated in the irrigation season.

$$\mathrm{OPUIA} = \frac{\text{Seasonal value of production}}{\text{Irrigated harvested area}} ---------------------(18)$$

Where:

OPUIA is output per unit irrigated cropped area

Seasonal production is the output of the irrigated area in terms of gross or net value of production measured at local price

Irrigated harvested area is the areas under crops

Output per unit command area (Birr/ha)

This indicator quantifies the value of production that obtained per unit command irrigable area. The computed value indicates the level of utilization or number of cropping frequency of the given command area in the production year and the productivity of the command area. High value result shows there is good intensive irrigation. Meanwhile small values are not pertinent from land productivity point of view; less intensity of irrigation could not increase the production amount per unit of land. Furthermore this is more relevant for land is the major constraint factor for production. Command area is the nominal or design area to be irrigated (Molden et al.,1998).

$$\mathrm{OPUCA} = \frac{\text{Seasonal value of production}}{\text{Command area(Nominal)}} ---------------------(19)$$

Where

OPUCA is output per unit command area

Seasonal production is the output of the irrigated area in terms of gross or net value of production measured at local price

Command area is the nominal or design area to be irrigated

Output per unit irrigation water supply (Birr/m^3)

This is one of the water productivity indicators and calculated as the total value of production per unit water diverted from the headwork to the command area throughout the irrigation seasons; it includes the conveyance losses in the irrigation systems. It illustrates the productivity of diverted water from the source. It is an important parameter where water is a scarce resource. Supplied irrigation water is the volume of surface irrigation water diverted to the command area can estimated by equation below (Sakthivadivel et al. , 1999).

$$\text{OPUIS} = \frac{\text{Seasonal value of production}}{\text{Total diverted irrigation water}} --------------------- (20)$$

Where

OPUIS is output per unit irrigation water supply or diverted

Seasonal production is the output of the irrigated area in terms of gross or net value of production measured at local price.

Total diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater

Output per unit water consumed (Birr/m^3)

This indicator derived from the general water accounting frame work (Molden et.al, 1998). Consumed water is the actual evapo-transpiration or process consumption from only irrigated crops (ET); it excludes other losses and water depletion from the hydrological cycle. The computed value does not affected by water losses through the system but only affected by the climatic feature of the area. It used to observe water consumption of crops at scheme level through evapo-transpiration relative to the diverted and delivered amount of irrigation water. It has a contribution for irrigation management aspects; to take measurements those minimize evapo-transpiration losses (Sakthivadivel et al. , 1999)..

$$\text{OPUWS} = \frac{\text{Seasonal value of production}}{\text{Total water consumed by the crop}} ------------------- (21)$$

Where OPUWS is output per unit water consumed

Seasonal production is the output of the irrigated area in terms of gross or net value of production measured at local price

Total volume of water consumed by ET is the actual evapotranspiration of crops

3.8.2 Water Use Performance Indicators

These indicators depict the state of water availability or shortage and how tightly supply and demand are related. Both RIS and RWS relate supply to demand and show some indication as the condition of water abundance or scarcity and how tightly supply and demand are matched.

Relative irrigation supply (RIS)

This is the ratio of annual irrigation supply (which excludes rainfall) to annual irrigation demand. Irrigation water is a scarce resource in many irrigation schemes and is a major constraint for production. This indicator is useful to assess the degree of irrigation water stress or abundance in relation to irrigation demand. It is the inverse of irrigation efficiency presented by (Bos, 1997).

Values of Relative Irrigation Supply (RIS) higher than one indicate that excess irrigation water is being supplied and RIS values greater than RWS values is a sign that major amount of water supplied in the area is from irrigation. The indicators are estimated as per the equations below (Molden et al., 1998):

$$\text{Relative irrigation supply} = \frac{\text{Irrigation supply}}{\text{Irrigation demand}} \quad (22)$$

Relative water supply (RWS)

This is the ratio of total annual water supplied (irrigation plus rainfall) to the annual crop water demand can estimated by equation below (Levine, 1982). It signifies whether the water supply is in short or in excess of demand.

$$\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Crop demand}} \quad (23)$$

3.8.3 Physical Indicators

According to Sener et al. (2007) developed a relation between currently irrigated areas to the command (nominal) area to be irrigated; to quantify the level of utilization of the potential irrigable area for irrigated agriculture for a particular production time period.

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. The selected indicator used for evaluation of physical performance is irrigation ratio which can be expressed as the follows (Molden et al., 1998).

$$\text{Irrigation ratio} = \frac{\text{Irrigated crop area}}{\text{Command area}} \quad (24)$$

Where irrigated crop area (ha) is the portion of the actually irrigated land (ha) in any given irrigation season and command area (ha) is the potential scheme command area.

3.8.4 Economic Performance Indicators

Finally the economic indicators deal with how much investment cost is spent on the project in comparison with total production and yearly maintenance and operation expenditure and whether system is self-sufficient or not. The economic performance indicators used in the evaluation for this particular study are gross returns on investment and financial self-sufficiency. The gross return on investment is calculated as the ratio of production to the cost of infrastructure at the irrigation scheme and the financial self-sufficiency was calculated as the ratio of revenue from irrigation to the total operational and maintenance expenditure (Vermillion, 2000).

$$\text{Gross return on investment} = \frac{\text{Production}}{\text{Cost of irrigation structure}} -------------(25)$$

$$\text{FSS} = \frac{\text{Revenue from irrigation charges}}{\text{Total operation and maintainance expenditure}} --------------- (26)$$

Where, FSS is financial Self Sufficiency

3.9 Water Delivery System Performance Indicators

The water delivery performance of the scheme was evaluated using some selected indicators, which are normally classified into four groups, namely adequacy, efficiency, equity and dependability.

3.9.1 Adequacy

The adequacy can be estimated for an irrigation system as whole, or for subsystem and command areas. Locally, for an off take, the adequacy is simply the ratio of actual to required delivery(Molden and Gates, 1990). The adequacy was computed using equation (27) and the values lower than one shows inadequate delivered water while the values higher than one shows that delivered water is more than enough.

$$P_A = \frac{1}{T}\sum_{T}\left(\frac{1}{R}\sum_{R} P_A\right);\ P_A = \frac{Q_D}{Q_R}\ \text{If } Q_D \leq Q_R \text{ otherwise } P_A = 1 -----------(27)$$

Where:

P_A is the performance measure relative to adequacy at subsystem or system level;

p_A is adequacy for a single point or simply delivery performance ratio;

Q_D is the actual amount of delivered water;

Q_R is the intended (required) amount of water;

R is region served by the system

T is time period (irrigation season).

3.9.2 Efficiency

Efficiency refers to the water conservation property of the system, i.e., its ability to minimize water losses due to oversupply. It is this efficiency at points of delivery that is concerned with in this research. The objective of water delivery efficiency is to conserve water by matching water deliveries with water requirements. A measure of this objective would be the spatial and temporal average of the ratio of Q_R to Q_D as shown in equation below (Molden and Gates,1990):

$$P_F = \frac{1}{T}\sum_{T}\left(\frac{1}{R}\sum_{R} p_F\right);\ p_F = \frac{Q_R}{Q_D} \quad \text{If } Q_R \leq Q_D \quad \text{other wise } P_F = 1 ---------- (28)$$

Where:

P_F is the performance measure relative to efficiency at system level

p_F is efficiency for a single point (e.g. off take);

Q_D is the actual amount of delivered water;

Q_R is the intended (required) amount of water.

R is region served by the system

T is time period (irrigation season)

Efficiency is lower than 1.0 when actual deliveries are greater than required. A system under water stress (Q_R>Q_D) always has a level of efficiency equal to 1.0. A good performance at system level, e.g. the total volume delivered is equal to the target, does not mean that all the units receive their due amount of water.

3.9.3 Dependability or Reliability

Dependability of water delivery is important to farmers because it allows for proper planning. According to Unal et al (2004) dependability expresses the ability to find water at the right time and in the place desired in the system. In this respect, dependability comes to mean that the water can be delivered at promised flow rate and duration. The major reason for low performance of irrigation systems are undependable water distribution. The uncertainty and undependability in the delivery may cause confusion and conflict among farmers. The degree of temporal variability in the ratio of amount delivered to amount required that occurs over a region or in other words dependability, may be measured through equation below (Murray-Rust and Snellen, 1993).

$$P_D = \frac{1}{R}\sum_{R} CV_T\left(\frac{Q_D}{Q_R}\right) ------------------------------(29)$$

Where:

PD is performance measure relative to dependability or reliability

$CV_T\left(\frac{Q_D}{Q_R}\right)$, is temporal coefficient of variation of the ratio of Q_D/Q_R over time period T.

The degree of temporal variability can be qualified by the value of indicator P_D. The closer the value of this indicator is to zero, the more reliable the relative delivery becomes over time.

3.9.4 Equity

The fair share of water may be based on a legal right for water, as in a prior appropriation system, or may be set as a fixed proportion of a water supply, as is done in many rotational delivery schemes. Equity of water delivery is a difficult objective to measure because there are many factors that determine the meaning of a fair share and because a fair share is often interpreted subjectively. However, it is important to define measures relating to equity so that systems can be designed or rehabilitated to deliver water in an impartial manner to users served by the system. This proposed measure is given by the equation 30 (Molden and Gates 1990):-

$$P_E = \frac{1}{T}\sum_{T} CV_R\left(\frac{Q_D}{Q_R}\right) ------------------------------(30)$$

Where:

PE is the performance measure relative to equity

$CV_R\left(\frac{Q_D}{Q_R}\right)$ is spatial coefficient of variation (ratio of standard deviation to mean) of the ratio Q_D/Q_R (relative water delivery) at delivery points over the hydraulic level or reaches R. As the value of P_E is close to zero, the degree of equity in water delivery would be higher.

Once the values of performance measures are estimated for a given state of a system, those values can be used to analyze the system for the purposes of evaluation and planning.

Table 3. 1. Performance standard for water delivery indicators

Measures	Performance classes		
	Good	Fair	Poor
Adequacy	0.9-1.00	0.80-0.89	<0.80
Efficiency	0.85-1.00	0.7-0.84	<0.70
Equity	0.00-0.01	0.11-0.25	>0.25
Dependability	0.00-0.10	0.11-0.20	>0.20

Source: Molden and Gates (1990)

3.10 Economic analysis of irrigation scheme performance

The productivity can be indicated by measuring these outputs in gross terms or relative to input utilized. The inputs of interest in irrigation are land, water and finance for different purpose of the system. Benefit-Cost ratio method was used for economic analysis of irrigation scheme.

$$BCR = \frac{PV(B)}{PV(C)} \qquad (31)$$

Where, BRC is benefit-cost ratio, PVB is present value of benefit and PVC present value of cost. The BCR shows the overall values for money of the project. If the ratio greater than one, the approach is acceptable.

4 RESULTS AND DISCUSSION

4.1 Soil Physical Properties

The soil textural classes in the project area were clay loam for the selected farms at upper head and middle reaches and sandy clay loam at tail end part of the irrigation scheme by using textural triangle (Appendix figure 1) and indicating that soils of the scheme at both upper and middle reaches are more or less similar in texture (Table 4.1). The bulk density values ranged from 1.15 to 1.25 g cm^{-3} at Sanko irrigation scheme. The bulk density values of the soils at both upper and middle part irrigation scheme were higher bulk density than tail end which has lower bulk density, since soil with textural class clay loam was more compacted than sandy clay loam. Volumetric moisture content retained at field capacity were 180 mm, 202.5 mm, and 96.6 mm at head, middle and tail end respectively, whilst the volumetric moisture content at permanent wilting point were 90 mm, 97.5 mm and 41.4 mm at head, middle and tail end parts of the scheme respectively and average field capacity and permanent wilting point of study area were 159.8 mm and 76.3 mm respectively. Values analyzed were between standard ranges according to the soil textural class. Furthermore, the total available water holding capacity of soil in selected fields from the scheme ranged from 55.2−105 mm m^{-1} as shown (Table 4.1).

Table 4. 1 Selected soil physical characteristics of the irrigation scheme

Field code	Soil depth (cm)	Particle size distribution (%)			Textural class	Balk density (g cm^{-1})	Average bulk density (g cm^{-1})
		Sand	Silt	Clay			
H	0-20	32	20	48	Clay loam	1.16	1.25
	20-40	28	32	40	Clay loam	1.27	
	40-60	34	30	36	Clay loam	1.32	
M	0-20	45	34	21	Clay loam	1.18	1.25
	20-40	25	30	45	Clay loam	1.25	
	40-60	30	40	30	Clay loam	1.33	
T	0-20	50	24	26	Sandy clay loam	1.05	1.15
	20-40	55	25	30	Sandy clay loam	1.17	
	40-60	53	20	27	Sandy clay loam	1.22	
	FC		PWP		Bd	TAW(mm)	RAW(mm)
	%	mm/m	%	mm/m	gcm^{-3}		
H	24	180	12	90	1.25	90	22.5
M	27	202.5	13	97.5	1.25	105	26.3
T	14	96.6	6	41.4	1.15	55.2	13.8

4.2 Irrigation Water Requirements of Onion crop in the Study Area

The seasonal and irrigation water requirements of the crop Onion, grown in the study area during the study period as estimated by the CROPWAT 8 model. The results indicated that for crop, the seasonal crop and irrigation water requirements were equal since there was no rainfall during the study period. Accordingly, the seasonal crop water requirement of onion, which was mainly practiced in the study area from November to March. The seasonal crop water requirement determined was at 414.71 mm (Table 4.2).

Table 4. 2 Seasonal crop water requirement for onion based on crop calendar

Months	Dev.stage	No-of days	Kc	ETo (mm/day)	ETc (mm/day)	ETc (mm/period)	ETc (mm/month
January	Dev.t	2	0.75	3.96	2.97	5.94	
	Mid	29	1.03	3.96	4.08	118.285	124.225
February		6	1.03	4.32	4.45	26.6976	
	Late	22	0.875	4.32	3.78	83.160	109.856
March		18	0.875	4.34	3.80	68.355	68.355
November	Initial	15	0.5	3.84	1.92	28.8	28.8
December		3	0.5	3.71	1.86	5.565	
	Dev.t	28	0.75	3.71	2.78	77.91	83.475
Seasonal ETc							**414.71**

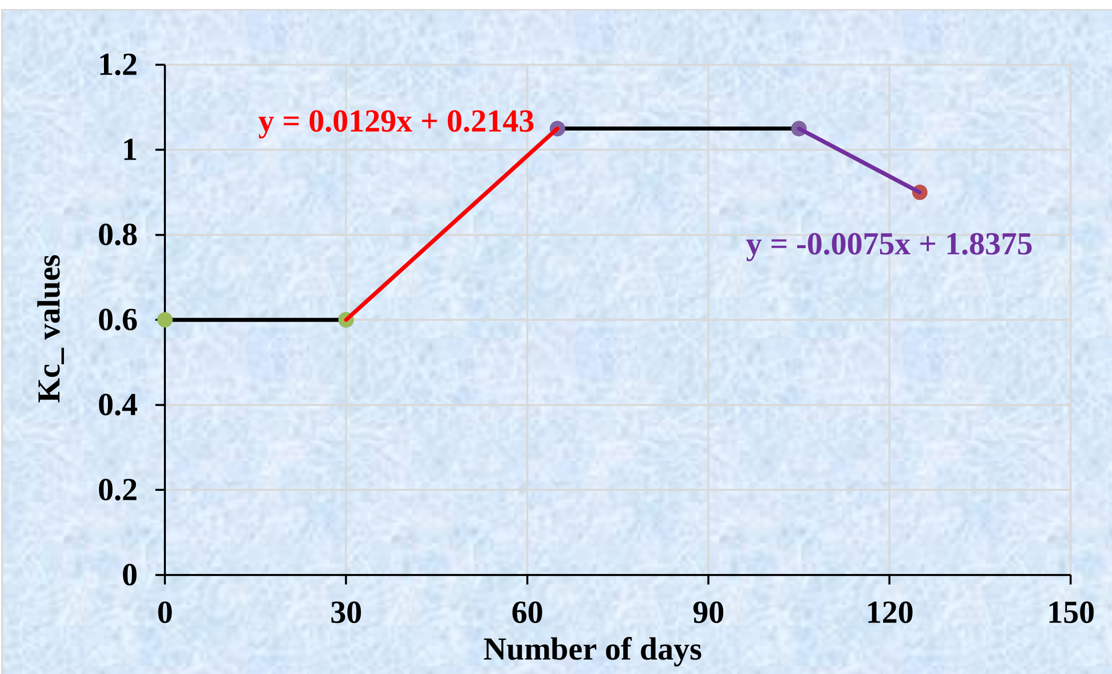

Figure 4. 1 Graphs growing period of Onion

4.3 Internal Process Indicators

4.3.1 Conveyance efficiency

The results of the conveyance efficiency evaluation revealed that this indicator varied within a at different points, of the scheme . The average conveyance efficiency values which indicate the amount of water lost during transportation of water from the diversion point or source to the outlet of the main canal of the scheme was 69.3% (Table 4.3). However, the values of conveyance efficiency for the Sanko irrigation scheme is below the recommended value i.e.70% unlined poorly managed main canals (MoAFS, 2002).

Table 4. 3 Average Conveyance Efficiency of Sanko small scale irrigation main canal

Canal Section	Average Water depth(m)	Average Width (m)	Area (m^2)	Length (m)	Time elapsed (sec)	Velocity (m/s)	Discharge (m^3/s)	Conveyance efficiency (%)
UMC	0.17	0.41	0.07	30	47	0.54	0.04	
LMC	0.15	0.42	0.063	30	58	0.44	0.028	69.3

UMC- upper main canal, LMC- lower main canal

4.3.2 Application efficiency

The application efficiency of a given irrigation scheme tells us whether the irrigation water is stored in the intended soil profile or lost as surface runoff and deep percolation. The application efficiency of selected fields at the Sanko irrigation scheme was 61.6%, 63.4% and 46.5% at head, middle and tail end of the scheme with an average application efficiency of 57.2%. A light soil with high infiltration rates favors deep percolation losses at the top of the fields, resulting in low field application efficiency. The details of application efficiencies for the selected fields of the scheme are shown in (Table 4.4). The finding indicates that the application efficiency of upper head and middle reach of irrigation scheme was slightly better than tail end part of irrigation scheme. This may be associated with the textural class of the soil and field furrow preparation. Generally the application efficiency of both upper head and middle reach of scheme are typical results for furrow irrigation (Savva and Frenken, 2002), which is recommended as 50-70% for properly designed furrow irrigation.

Table 4. 4 Average field application efficiency of Sanko small scale irrigation scheme

Field code	Moisture before irrigation	Moisture after irrigation	Moisture stored(mm)	Water applied(mm)	Ea	Average Ea
H_1	17.04	37.45	20.41	31.4	65	61.6
H_2	15.81	34.75	18.94	31.4	60.3	
H_3	14.40	33.07	18.67	31.4	59.5	
M_1	16.88	38.11	21.23	32.5	65.3	63.4
M_2	13.84	34.11	20.27	32.5	62.4	
M_3	15.65	35.93	20.28	32.5	62.4	
T_1	16.65	27.14	10.49	21.0	50	46.5
T_2	14.79	24.86	10.07	21.0	48	
T_3	16.20	24.91	8.71	21.0	41.5	
Average application efficiency of the system						**57.2%**

4.3.3 Deep percolation ratio

Deep percolation ratio indicates the irrigation applied to a field percolates into the soil below the root zone. As depicted in table 4.5 average deep percolation ratio at irrigation scheme was found to be 42.8%. In the schemes, there is high deep percolation ratio which indicates over irrigation.

4.3.4 Storage efficiency

The result of storage efficiency of selected fields from irrigation scheme were 86%, 74.8% and 71% at head, middle and tail end of the irrigation scheme respectively with an average storage efficiency of 78.5% (Table 4.5). In general the storage efficiency of the scheme was very good as compared to 63% storage efficiency usually found in typical furrow irrigation systems (Raghuwanshi and Wallender, 1998).

4.3.5 Overall Scheme Efficiency

The overall efficiency of the scheme is the ratio of water made available to the crop to the amount released at the headwork. In other words, it is the product of conveyance efficiency and application efficiency. In the present study the overall efficiency of the irrigation scheme was 39.6% (Table 4.5). The result indicated that the irrigation scheme was relatively poor. The overall efficiency values (40-50%) commonly observed in other similar African irrigation schemes (Savva and Frenken, 2002).

Table 4. 5 Different values of selected internal performance indicators of the scheme

Internal performance Indicators	Average values obtained from the scheme
Conveyance efficiency(Ec)	69.3%
Application efficiency(Ea)	57.2%
Dee percolation ratio(DPR)	42.8%
Storage efficiency(Es)	78.5%
Overall scheme efficiency(Ep)	39.6%

4.4 Productivity Performance Indicators

4.4.1 Irrigated agriculture performance indicators

This includes performance indicators, which are associated with the production. The major of such performance indicators included are output per unit cropped area, output per unit of command area, output per unit irrigation supply and output per unit water consumed.

4.4.1.1 Output per unit cropped area

The output per unit cropped area shows the response of each cropped area on generating gross return. This parameter gives a clue about the management practice in every scheme. According to the yield collected and evaluated from each of three reaches of the irrigation scheme; the outputs per unit cropped area were 84,705.88 Birr per command area, 220,689.6 Birr ha^{-1} and 69,689.4 Birr ha^{-1} from head, middle and tail end of the scheme respectively and an average value of output per unit cropped area of 125,027.3 Birr ha^{-1}(Tables 4.6) of output was obtained form from the irrigation scheme. Based on this evaluation it is possible to say that the response or income per cropped area at middle part of the irrigation scheme was relatively better than that of tail end of irrigation scheme. This income reduction in upper and tail end of the irrigation scheme was mainly due to over irrigation beyond crop water requirement and under irrigation respectively.

4.4.1.2 Output per unit of command area

This indicator expresses the average return per design command area. It is an indication of whether all the command areas are generating returns or not. The outputs per unit command area of irrigation scheme was 15,003,276 Birr per command area. Which was very low production value as compared to 76,800,000 Birr per command area for good yield bulb under irrigation as stated in (FAO 1986). The details of outputs per unit command area in the irrigation scheme are shown in Table 4.6

4.4.1.3 Output per unit irrigation supply

The outputs per unit irrigation supply show the revenue from agricultural output for each meter cube of irrigation water supplied. The outputs per unit irrigation supply at the three level of the scheme were 13.5 Birr m^{-3}, 33.95 Birr m^{-3} and 22.12 Birr m^{-3} at head, at middle and at tail end of the scheme respectively and an average output per unit supply of the scheme was 23.2 Birr m^{-3}. This indicates that production value per unit irrigation supply in middle reach is better than head and tail reach. Higher value of this indicator in the middle reach indicates lower irrigation supply and lower value obtained in upper and tail end of the scheme indicates lower production due to over irrigation and under irrigation respectively.

4.4.1.4 Output per unit water consumed

The output per unit water consumed is used to describe the return on water actually consumed by the crop. This indicator gives due attention to the water consumed by the scheme and tells us how water is efficiently utilized. The outputs per unit water consumed in this study were 20.41 Birr m^{-3}, 53.18 Birr m^{-3} and 22.12 Birr m^{-3} at head, middle and tail end part of the irrigation scheme and an average output per unit water consumed of the scheme was 34.93 Birr m^{-3}. This result shows that the water use efficiency in the middle part of the scheme was good as compared to outputs per unit water consumed at upper and tail part of the scheme. Lower return on water consumed in upper and tail end part of irrigation scheme was over irrigation and under irrigation in the system respectively (Appendix figure 7 and 9). Lower return on water consumed was not only result of water scarcity but excess water would not improve the productivity but could reduce it.

4.4.2 Water use performance indicators

4.4.2.1 Relative water supply

The relative water supply depicts whether there is enough irrigation water supplied or not. Both the relative water supply and relative irrigation supply relate supply to demand and give some indication as the condition of water abundance or scarcity and how tightly supply and demand is matched. The relative water supply value below one normally indicates that the water applied is less than the crop demands and values above one indicate extra water is added to the root zone beyond plant demands. In this study the relative water supply in the three stages of the system were 1.51, 1.57 and 0.76 at head, at middle and at tail end of the system level and an average relative water supply of 1.28 (Table 4.6). The results in upper and middle parts of the scheme which was greater than one represents the supply is enough to meet the crop insist but at the tail end part of the system, the result was less than one which indicates that there was less amount of irrigation water diverted to the field below crop demands. In order to maximize water use efficiency of the scheme, it is required that the amount of water supplied to be reduced in both upper head and middle reaches of the scheme and amount of water supplied to be maximized in the tail end part of the system.

4.4.2.2 Relative irrigation supply

The relative irrigation supply shows whether the irrigation demand is satisfied or not. Since there was no rainfall in the area during study period; the value of relative irrigation supply and relative water supply is the same which means 1.51, 1.57 and 0.76 at head, at middle and at tail end of the system and the result indicates that there is irrigation water scarcity at the tail end of the scheme which is less than crop water requirement (Appendix table 3).

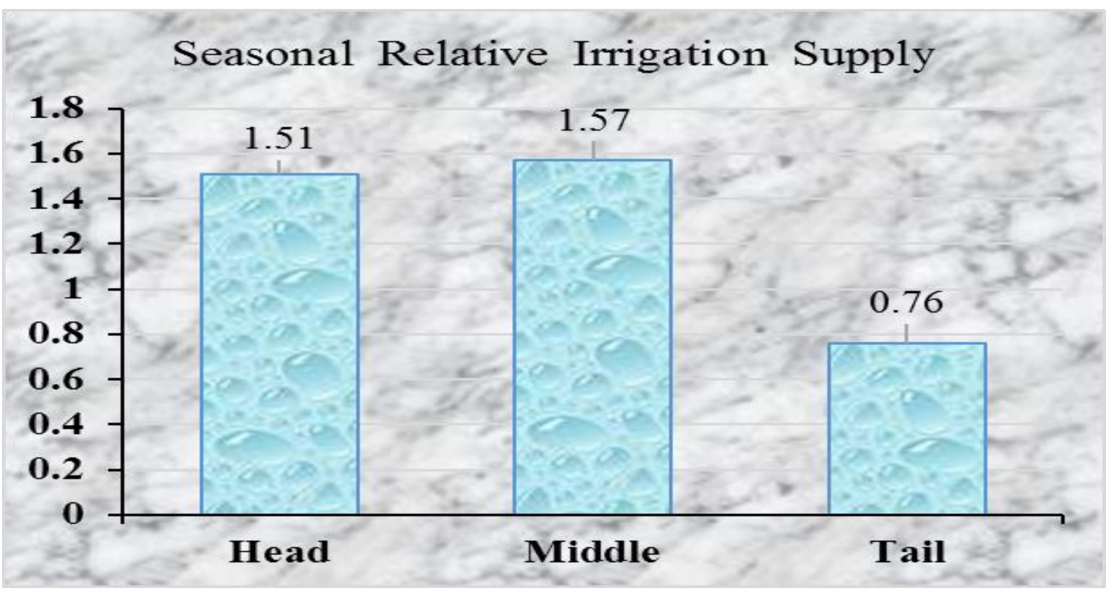

Figure 4. 2 Seasonal relative irrigation supply

4.5.3 Physical performance indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. Irrigation ratio for the Sanko irrigation scheme was 1.00, which means that

100% of command area was under irrigation and additional 25 ha expansion was under construction during the study period (Appendix figure 10).

4.5.4 Economic performance indicators

4.5.4.1 Gross return on investment

This indicator considers the production and the total cost of infrastructure for the irrigation scheme. The result 4.7 implies that the gross return on investment was relatively good as compared to benefit cost ratio greater than or equal to one. The details of the gross return on investment of scheme is shown in Table 4.6

4.5.4.2 Financial self-sufficiency

Financial self-sufficiency indicates the ratio of revenue from the irrigation users' to the expenditure for operation and maintenance. The total operation and maintenance cost was 1,980,992.59 Birr of which 1,181,534. 45 Birr for head work maintenance and 799,458.14 Birr for tail end part maintenance of irrigation scheme and the annual revenue from irrigation users' was 648,000 Birr which was very low according to cost expended for operation and maintenance. The financial self-sufficiency of this particular research value 0.33 indicated that the revenue collected from irrigation charges was not sufficient for operation and maintenance of the project. As a result, the government covers the operation and maintenance cost of the irrigation scheme and it is considered as subsidy and irrigation scheme was not maintained and extra amount of irrigation water lost from the system(Appendix figure 4). Economic performance indicators showed that the scheme had a serious problem about the collection of water fees. Detail explanation of financial self-sufficiency of the Sanko irrigation project was presented in (Table 4.6).

Table 4. 6 Different values for selected external performance indicators of the scheme.

External Indicators		Average value obtained from the scheme
Agricultural Performance	Output per cropped area(Birr ha^{-1})	125,027.3
	Output per unit cropped area(ton ha^{-1})	7.81
	Output per unit command area (Birr per command area)	15,003,276
	Output per irrigation supply (Birr m^{-3})	23.2
	Output per unit water consumed (Birr m^{-3})	31.9
Water use Performance	Relative water supply (ratio)	1.28
	Relative irrigation supply (ratio)	1.28
Physical performance	Irrigation ratio	1
Economic performance	Gross return on investment(ratio)	4.7
	Financial self-sufficiency(ratio)	0.33

4.6 Water Delivery System Performance Indicators

4.6.1 Adequacy of water delivery

Adequacy values in the upper, middle and tail end part of irrigation scheme were 0.79, 0.82 and 0.31 respectively (Table 4.7) and which indicates fair amount delivered in middle part of the scheme according to standard between 0.80 and 0.89 for fair and poor amount of water delivered in upper and tail part of the scheme according to standard value less than 0.8.

4.6.2 Efficiency of water delivery

Efficiency values of irrigation water delivery in upper, middle and tail end part of the scheme were 0.31, 0.29 and 0.58 respectively. The value indicates that irrigation water delivery through the system level was poor according to standard value less than 0.70 for poor water delivery.

4.6.3 Dependability of water delivery

Dependability values of irrigation water delivery in upper, middle and tail end part of the scheme were 2.4, 2.5 and 0.30 respectively(Table 4.7). The values indicate that irrigation water delivery was poor according to standard value more than 0.20 for poor irrigation water delivery.

4.6.4 Equity of water delivery

The equity values of irrigation water delivery in upper, middle and tail end part of the scheme were 1.8, 1.9 and 0.27 respectively (Table 4.7). The values indicate that irrigation water delivery was poor in parts of irrigation scheme according to standard value above 0.25 poor irrigation water deliveries and fair water delivery in tail end part of the scheme according to standard value between 0.11− 0.20 for fair water delivery.

Table 4. 7 Water delivery performance indicators of Sanko irrigation scheme

Measures	Head	Middle	Tail
Adequacy	0.79	0.82	0.31
Dependability	2.4	2.5	0.30
Efficiency	0.31	0.29	0.58
Equity	1.8	1.9	0.27

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The performance evaluation of the Sanko irrigation scheme indicated that the availability of irrigation water is not a constraint at farm level and higher amount of water was diverted in upper and middle part of the system. Since the intension of analysis to investigate how consistent or how the performance of irrigation scheme was consistent with respect to the irrigation system. The conveyance efficiency of the scheme at the level showed some low values, even in the lined part of the main canal due to lack of regular maintenance, sediment deposition, use of illegal diversion gates for irrigation water. The application efficiencies in both upper and middle reach of the scheme has however, showed good when compared with application efficiency of 50-70% for furrow irrigation observed in other African countries.

The relative water and irrigation supply for both upper and middle reaches show that there is ratio greater than one, which implies the amount of water applied during irrigation events, was much higher than what was required by crop. This type of irrigation affects the crop production by reducing aeration for crop planted, water logging and also causes water wastage that can cultivate extra fields. But in tail end of the scheme lower ratio of relative water and irrigation supply which indicates amount of water applied during study event was much lower than desired amount of water to be applied. The output per cropped area at upper and tail end was extremely low as compared to middle reaches of the scheme, implying that the irrigation practice in upper and tail end of the scheme was relatively poor due to over and under irrigation respectively. In general output per unit command area was observed relatively low in Sanko irrigation scheme as compared to a good bulb yield under irrigation in Irrigation and Drainage paper 33. Therefore for the improvement of the irrigation system management and the irrigation practice frequent performance evaluation is very important. According to the results obtained, water management practice of Sanko irrigation scheme was generally very poor. The financial self-sufficiency of Sanko scheme was observed severely low which is a major obstacle to the sustainability of the scheme. Economic performance indicators showed that the scheme had a serious problem about the collection of water fees due to lack of awareness creation about irrigation scheme and irrigation water. Generally irrigation water delivery performance in Sanko small scale irrigation scheme was not good due to lack of proper irrigation water management, lack of unfair irrigation distribution, lack of proper irrigation scheduling, lack of considering crop water requirement and lack of operation and maintenance irrigation scheme thought system level.

In general, based on the evaluation carried out, it can be concluded that yield obtained from Sanko irrigation scheme at the middle part of the scheme was relatively better than the upper and tail end part of the scheme .This was due to the fact that the system permitted farmers to apply large and small volume of water to their fields as shown in appendix figure 7 and 8 respectively combined with poor knowledge about crop water requirement. The study covered the minimum set of indicators that can be used to evaluate the health of the system. The small number of samples cannot permit a deep analysis of the indicators, but the study showed the usefulness of the indicators. The method can be useful tool in performance measurement and in the discovery of possible improvement needed.

5.2 Recommendations

Huge amount of money has been invested to operation and maintenance in addition to investment cost for construction of Sanko modern irrigation scheme and farmers are expected to use water efficiently. Even though there was no sign of being unproductive from the time of the irrigation establishment, irrigation water considerably wasted by farmers themselves. Farmers should be advised to appropriate irrigation water management so as to get much return from the production. Assigning DAs and office assistants for improvement of irrigation scheme and used as mechanism to develop healthy perception of farmers about irrigation water.

Earlier to developing an irrigation scheme for farmers, the capability of farmers whether they manage it or not must be considered. And close monitoring should be practiced than completely left the operation and maintenance for farmers. Especially issues like crop water requirements have to give much emphasis. Improvement of irrigation efficiency of the scheme needs tackling of all problems around area of water management and the infrastructure. Farmers at the head and middle of the system generally apply more water than needed for potential yield and excess water not improve the productivity but was reduce it. Instead the excess water were diverted to tail end part of the scheme receiving less water than needed to produce potential yields, then the production would have increased. Therefore to reduce over and under irrigation, the farmers should be get awareness about how to use, when to use and how much water used on their fields.

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7 APPENDICES

7.1 Appendix I. Tables

Table 1. Average climatic data of the study area

Months	Min Temp (^0C)	Max Temp (^0C)	Humidity %	Wind (km/day)	Sun (hours)	Rain fall(mm)	ETo(mm/day)
January	14.7	26.9	60	95	7.9	41.8	3.96
February	14.9	27.4	63	63	8.2	57.4	4.32
March	15.5	27.3	68	181	6.1	107.3	4.34
April	15.2	24.9	72	130	7.3	142.3	4.15
May	14.9	23.7	76	112	5.4	132.4	3.45
June	14.4	22.5	76	104	5.6	108.1	3.29
July	14.1	21.9	62	95	5.1	104.9	3.35
August	14.1	22.2	59	104	3.8	107.4	3.28
September	14.3	23.2	62	66	5.4	120.5	3.55
October	14.3	23.7	78	95	6.7	127.3	3.58
November	14.9	24.8	57	78	8.1	99.1	3.84
December	13.8	25.8	67	69	8.4	46.8	3.71
Average	14.6	24.5	67	104	6.5	99.6	**3.74**

Table 2. Average yield and average output per cropped area of irrigation scheme

Field Codes	Yield obtained (Kg/ha)	Average yield obtained (kg/ha)	Average yield obtained (ton /ha)	Output per cropped area (Birr/ha)	Average output per cropped area (Birr/ha)
H_1	5,330.88	5,294.12	5.3	85,294.08	84,705.87
H_2	5,367.65			85,882.4	
H_3	5,183.82			82,941.12	
M_1	13,695.20	13,793.10	13.8	219,123.2	220,689.6
M_2	14,893			238,288	
M_3	12,791.10			204,657.6	
T1	4,365.20	4,355.40	4.4	69,843.2	69,686.4
T2	4,453.60			71,257.6	
T3	4,247.40			67,958.4	

Table 3. Q_D and Q_R values of each month of irrigation at the field level

Field code	Months of irrigation	Q_R(mm/month)	QD(mm/month)	Number of actual irrigation days/months
H	November	28.8	125.6	4
	December	83.48	157	5
	January	124.23	188.4	6
	February	109.86	94.2	3
	March	68.36	62.8	2
M	November	28.8	130	4
	December	83.48	162.5	5
	January	124.23	195	6
	February	109.86	97.5	3
	March	68.36	65	2
T	November	28.8	21	1
	December	83.48	84	4
	January	124.23	105	5
	February	109.86	63	3
	March	68.36	42	2

Table 4. Applied irrigation water measurement (Flume average) at Sanko irrigation project

Field code	Areas of field (m^2)	Time elapsed (min)	Flume height(cm)	Respective discharge(l/s)	Depth applied(cm)
H	272	44.5	7.6	3.2	3.14
M	435	69.2	7.9	3.4	3.25
T	229.6	48	5.0	1.7	2.1

Table 5. Free flow discharge values for different inch parshall flumes

Head (cm)	Throat width (inches)				
	1	2	3	6	9
	Discharge (l/s)				
2	0.140	0.281			
3	0.263	0.526	0.772	1.496	2.504
4	0.411	0.822	1.206	2.357	3.889
5	0.581	1.162	1.705	3.354	5.471
6	0.771	1.541	2.261	4.473	7.232
7	0.979	1.957	2.872	5.707	9.155
8	1.205	2.407	3.532	7.047	11.231
9	1.446	2.889	4.239	8.489	13.448
10	1.702	3.402	4.991	10.027	15.801
11	1.973	3.943	5.786	11.656	18.281
12	2.258	4.513	6.621	13.374	20.885
13	2.557	5.109	7.496	15.177	23.605
14	2.868	5.731	8.408	17.062	26.440
15	3.191	6.377	9.358	19.027	29.383
16	3.527	7.048	10.342	21.070	32.433
17	3.875	7.743	11.361	23.188	35.585
18	4.234	8.460	12.413	25.38	38.837
19	4.604	9.200	13.499	27.643	42.186
20	4.985	9.961	14.616	29.976	45.630
21	5.376	10.744	15.764	32.379	49.167
22		11.547	16.942	34.848	52.794
23			18.151	37.384	56.510
24			19.389	39.984	60.312

7.2 Appendix II. Figures

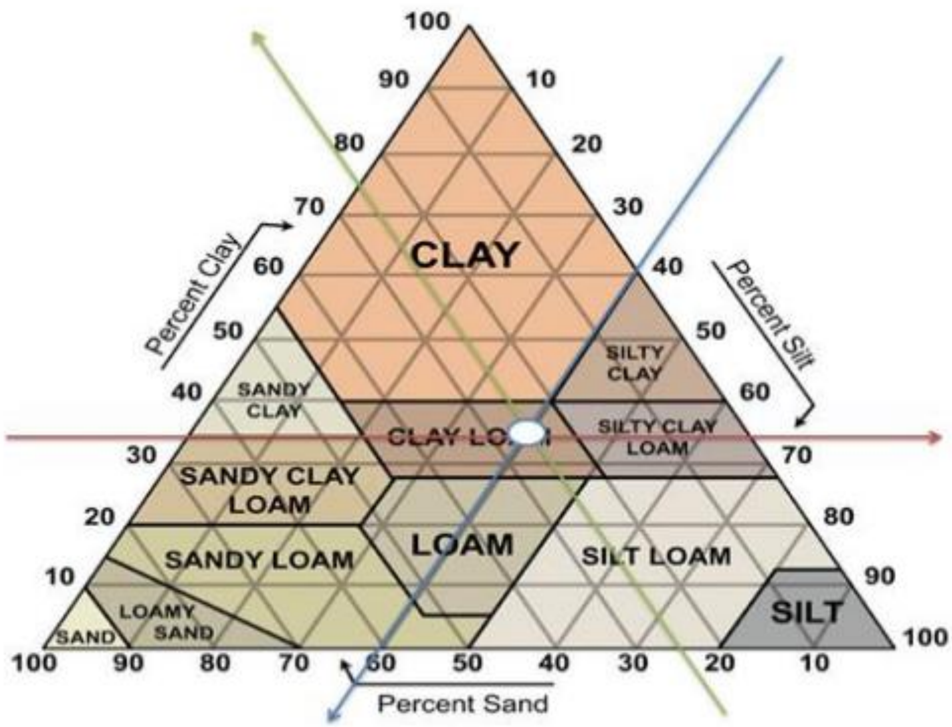

Figure 1. Determination of soil textural class on textural triangle

Figure 2**.** Soil sampling before and after irrigation from different depth

Figure 3**.** Core sampling auger and measuring weight of soil

Figure 4. Maintaining and repairing of head work parts of Sanko irrigation scheme

Figure 5. Using earthen materials and stones for opening and closing diversion gates

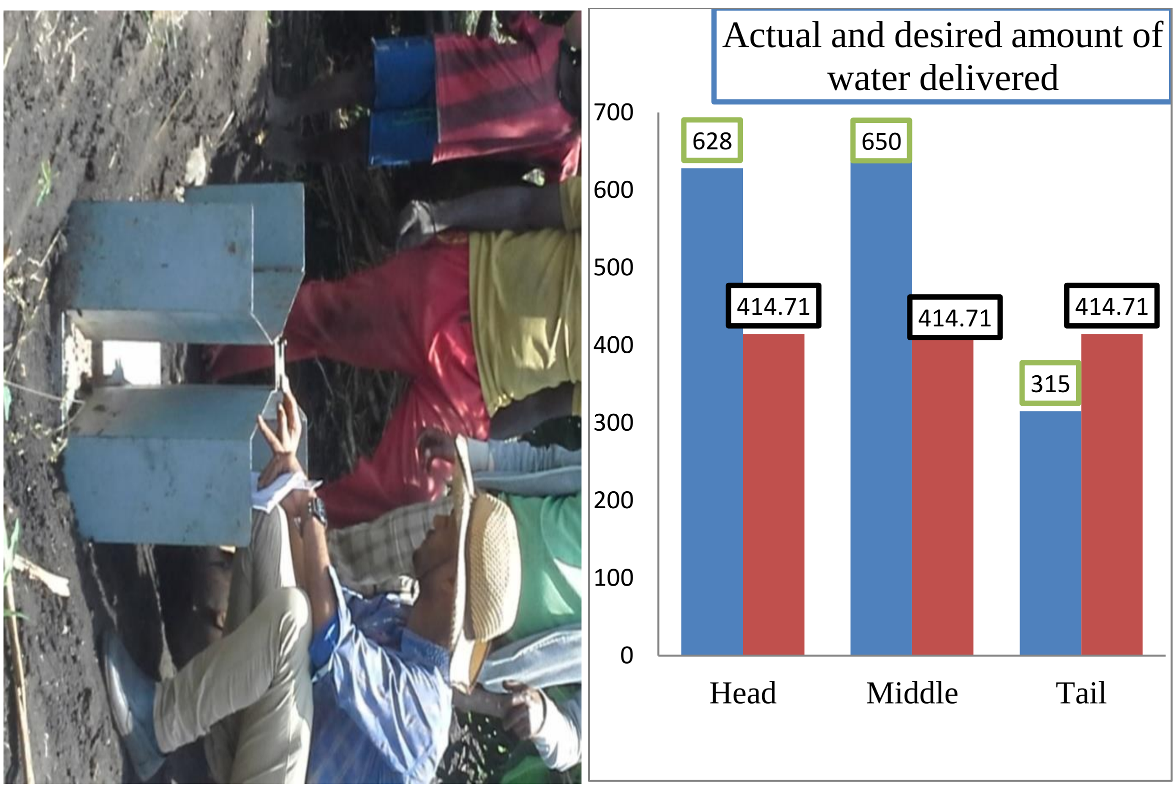

Figure 6. Actual and desired amount of water on leveled 3-inch parshall flume

Figure 7. Effect of over irrigation at upper head part of the scheme

Figure 8. Irrigation water application at development stage in middle part of the scheme

Figure 9. Unmaintained irrigation canal and wilted Onion at the tail end part of the scheme

Figure 10. Additional construction of irrigation canal as extension

Figure 11. Irrigation water was flowing in to forests without considering where it going