JIMMA UNIVERSITY

SCHOOL OF POST GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDRAULIC ENGINEERING PROGRAM

CHARACTERIZATION AND PERFORMANCE EVALUATION OF SMALL SCALE IRRIGATION SCHEME; THE CASE ASHAR AMHARA REGION, ETHIOPIA

By

Tsegaye Geremew

A Research Submitted to School of Graduate Studies of Jimma Institute of Technology in Partial fulfillment of the requirements for the Degree of Masters of Science in Hydraulic Engineering.

Dec 15, 2018

Jimma, Ethiopia

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Tsegaye Geremew

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Dec 15, 2018

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DECLARATION

I, the undersigned, declare that this thesis entitled **"characterization and performance evaluation of small-scale irrigation scheme; the case of Ashare Amhara, Ethiopia"** is my original work, and has not been presented by any other person for any award of a degree in this or any other University, and all source of material used for these have been dually acknowledged.

Candidate:

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Date: ----/----/------

As master's research Advisors, we here that we have read and evaluate this MSc Research prepared by Tsegaye Geremew under our guidance, entitled; **"characterization and performance evaluation of small-scale irrigation scheme; the case of Ashare Amhara Ethiopia"** We recommended that it can be submitted as fulfilling the MSc thesis requirements.

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ABSTRACT

Irrigation is one means by which agricultural production can be increased to meet the growing demands. The principal objective of evaluating the performance of irrigation scheme is for a variety of reasons: to improve system operations; to assess progress against strategic goals; as an integral part of performance-oriented management, to assess the general functionality of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance. While conducting this study, initial assessment and field observation, consultation with different stalk holders was made to visualize the study area. The scheme characterization was made by measuring the canals discharge capacity, dimensions, length of flow and functionality of the structures, using selected performance indicators such as conveyance, application, storage, distribution uniformity and overall efficiencies along with the water productivity in terms of water use efficiency. Conveyance efficiency of canals was estimated using area velocity method at different cross section of the canals. For crop water demand, the FAO's computer program CROPWAT8 package was utilized to calculate the crop water requirements. Average conveyance efficiencies were obtained as 61.21%,59.95% and 62.97% in head, middle and tail end location of the scheme respectively. The application efficiencies were 62.67%, 52.58% and 52.32% in head, middle and tail end location of the scheme respectively. The average storage efficiency for all fields was 52.64%. The distribution uniformity was found to be 88.63%, 87.52% and 91.47% for upstream, middle and downstream location of test plots respectively. The losses were only deep percolation as the furrows were close ended. The deep percolation ratio was found in the range of 47.68% in tail location farm to 37.33% in head location's. The average overall scheme efficiency for all fields was 34.15%. Finally, the economic water use efficiency of test plots in terms of benefit-cost ratio were estimated and found as 1.83, 2.04 and 2.27 for head, middle and tail locations, respectively and found to be efficient.

Key words: Characterization, CROPWAT8, FAO's, irrigation project and Performance.

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ACRONYMS

CO-SAERAR	Commission for Sustainable Agriculture and Environmental Rehabilitation in Amhara Region
CROPWAT 8	Crop Water Requirement Estimation Model Window 8
ETB	Ethiopian Birr
ETc	Crop Evapotranspiration
ETo	Reference Evapotranspiration
FAO	Food and Agricultural Organization
ICID	International Commission for Irrigation and Drainage
IFPRI	International Food Policy Research Institute
IWMI	International Water Management Institute
JIT	Jimma Institute of Technology
KC	Crop Coefficient
LIVES	Livestock and Irrigation Value chains for Ethiopian Smallholders
MAD	Moisture Allowable Deficit
MoAFS	Ministry of Agriculture and Food Security
MoARD	Ministry of Agriculture and Rural Development
MoWR	Ministry of Water Resource
RPIP	Research Program on Irrigation Performance
UTM	Universal Transverse Mercator
WAPCOS	Water and Power Consultancy Services
WUA	Water Users Association

1. INTRODUCTION

1.1. Background

Irrigated agriculture requires intensive management as compared with rain fed agriculture and the land holding size per household has significant impact on effectively managing the land in a more productive manner (MoA, 2011). Rapid increase in the world's population have made the efficient use of irrigation water vitally important, particularly in poorer countries, where the greatest potential for increasing food production and rural incomes if often to be found in irrigated areas. It has therefore become a matter of serious concern in recent years that, despite their very high costs, the performance of many irrigation schemes has fallen for short of expectations.

Irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia. A study also indicated that one of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales through river diversion, constructing micro-dams, water harvesting structures, etc. (Sileshi B. et. al., 2007).

Irrigation system evaluation is characterized by complex number of factors that play significant role in determining the level of its performance. Although the researches done earlier provided valuable performance results, they needed to be attached with specific targets and the system of evaluation that would be flexible to include reasonably large number of evaluation factors. The factors would thus be usable by irrigation planners and managers. Poor distribution and management of irrigation water is a major factor contributing to inefficient situation. Adequate monitoring and evaluation of performance are needed to improve water management practices in order to achieve an increase in overall efficiency (Sarma and Rao, 1997). Evaluation of irrigation system is a tool that is used for determining the irrigation performance indices, Application Efficiency (Ae), Distribution Uniformity (Du) etc, to gather information as to know whether the system is operating below or above selected critical levels and to take management decisions for making corrective measures. In effect, the evaluation process examines, the design criteria such as field layout, irrigation flows, and scheduling, adopted at the farm development phase.

There is increasing pressure to improve the water use efficiency of irrigated agriculture in developing countries. Over irrigation and excessive drainage losses are widespread. Significant water savings can be achieved with an integrated approach to irrigation and drainage management (Brown, 2003). As exemplified by studies of inter-sector allocation of water in irrigated river basins, focus is now being made to improve surface irrigation efficiency with the aim of “sparing water” for inter-sector needs (Brown, 2003).

Ethiopia faces four key technical, Scio-economic, institutional, and environmental challenges that must be overcome in order to meet this ambitious target: behind-schedule delivery, low performance of schemes, constraints on scale-up of irrigation projects, protecting irrigation development sustainability (IWMI, 2010). In most cases people believe that irrigation schemes with modern system will have high performance but use of modern methods of field application alone does not guarantee high performance. Performance of an irrigation system depends as much or more on the WUA and farmers of irrigator as on the quality of the system.

Low level of performance can be identified at any level and stage of irrigation system. At system level, the status of cropping intensity, irrigation intensity, and yields from many irrigated areas are usually unsatisfactory. Reports indicate that the economics of irrigated agriculture are such that many farmers have not been able to achieve a more prosperous and healthy life. At the level of water distribution there are innumerable references in the form of inequity of water distribution leading to major disparities between head and tail areas, deficit water supplies and loss of production in some locations, or excess water delivery. These low performances occur in irrigation though it is a technological package that feeds billions of people. Good performance is not only a matter of high output, but also one of efficient use of available resources (Rust and Snellen, 1993).

Improving irrigation performance to increase productivity is one of the main visions formulated by international organizations involved in water development. Water productivity for food production was a major issue at the Second Water Forum held in March 2000 organized by the World Water Council in The Hague, where a frame work for achieving water security was formulated. The conference set a target to increase food productivity of water by 30 percent by the year 2015 (FAO, 2002). This goal calls for evaluation of irrigation systems aimed at increasing farm performance.

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). A plant with adequate nutrition can generally better withstand water stress (Gonzalez-Dugo et al., 2010; Waraich et al., 2011). Thus, to be meaningful, the metrics used to express the performance of agricultural inputs, such as fertilizer use efficiency and water productivity, should be analyzed together, and in combination with complementary indicators reflecting the overall effectiveness of the farming system, including crop yield and soil nutrient levels.

A number of small scale irrigation schemes have been designed and constructed in Amhara region in the previous years. The types of the schemes include river diversions, intakes and micro-earth dams. Especially since 1995/96G.C, many schemes were implemented in different parts of the region by CO-SAERAR. The size of irrigable land goes up to 200 ha. Most of these schemes are currently in operation. However, some of the schemes are not operating with full capacity as a result of various reasons. Such reasons, among others, include frequent reorganization of the responsible bureau and rapid staff turnover, limited staff capacity, technical know-how, problems associated with the legal empowerment of WUAs, and the lack of community participation in the development process (Michael M. and Sileshi B., 2007).

The performance of irrigation operation has to be evaluated periodically, both at system and at farm levels, using indicators that have been established. Hence, this study was undertaken with the objective of characterizing and evaluating the performance of Asher small-scale irrigation scheme in South Achefer and Dangila Woreda of Amhara Region, Ethiopia

1.2. Statement of the problem

Irrigated agriculture has made a major contribution to the food production and food security throughout the world. Without irrigation, much of the impressive growth in agricultural productivity over the last 50 years could not have been achieved. Nevertheless, it is widely accepted that the overall performance of irrigation and drainage investments has too often been fallen short of the expectations of planners, governments and financing institutions (FAO,1989).

Ethiopia has an estimated irrigation potential of 3.7 million hectares (ha) of land (Awulachew *et al*., 2010). During 2006, the total estimated area of irrigated agriculture in the country was 625,819 ha, which, in total, constitutes about 17% of the potential (MoWR, 2010). Despite its enormous potential to boost the country’s economy irrigated agriculture is facing a number of problems. One of the major concerns is the generally poor efficiency with which water resources have been used for irrigation. A relatively safe estimate is that 40 percent or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff (FAO, 1989).

Whereas in Amhara region though quite a large number of irrigation schemes have been constructed and are in operation, a comprehensive assessment and evaluation of the performance of diversion scheme has not been done yet. Most of the diversion schemes are not working with full capacity, the structures (weir components) deteriorated before their service life [Muluken L., 2008]. They require maintenance after the flood season and some of them are even left unused due to technical (design as well as construction) problems and lack of ownership feeling by the beneficiaries.

More generally the key factors accountable for the poor performance of irrigation schemes can be summarized as problem related to operation and maintenance, sustainability of surface water resources, issues related to watersheds and environmental management, lack of standard improved agronomic and on farm water management (crop selection, soil fertility and irrigation scheduling, equity, cost recovery and agricultural productivity) (Awulachew,2010).

Despite the poor performance of the irrigations in the country, evaluation of small-scale irrigation systems is not common. According to Pereira and Trout, (1999), field evaluations play a fundamental role in improving surface irrigation systems. They provide the information required for design, model validation, and mainly for advising irrigators on how to improve their systems and management practices.

There is no any such comprised research in this part of the region. Hence, this study initiated to alleviate these drawbacks and attempts to introduce the concept of characterization and assessments of the existing irrigation system as a tool to evaluate the performance of small-scale irrigations endeavors in Awi zone.

1.3. Objective of the study

1.3.1 General objective

The general objective of the study is to characterize and evaluate the level of performance of irrigation system under the existing farmer's irrigation management practices using selected performance indicators for betterment of scheme water management practices and sustainable irrigated agricultural development.

1.3.2 Specific objective

The specific objectives of the study are:

1. To characterize the existing irrigation schemes in terms of resource characterization such as water and soil characterization.

2. To assess the technical performance of Ashar Irrigation project.
3. To evaluate the economic performance of the scheme.

1.4. Research question

1. How are irrigation schemes performing under the existing farmer's irrigation management practices is characterized for betterment of scheme water management practices?

2. What are the measured values of technical performance efficiency of Asher irrigation scheme?
3. How are the economic performance efficiency of the scheme is estimated?

1.5. Significance of the study

Irrigation technology is one means by which agricultural production can be increased to meet the growing demand for food. This implies that irrigation is one of the ranges of technologies available to increase agricultural production and maximize household income to improve rural livelihood. Thus, this study primarily focused on characterizing the scheme, as well as technical and economic performance evaluation of Ashar irrigation schemes, assessing their determinants of intensity of irrigation water use. The results are expected to be useful for policy makers and different organizations that are involved in the promotion of irrigation development in the region and at national level.

The results of the study could also make its own contribution as base line information for further studies on the economic aspects of irrigation water use. The results of the study on the factors that determine the willingness of the users to maintain, keep and manage the scheme elements determinants of irrigation water use decisions, which is vital for the government, policy makers and irrigation users that leads to using irrigation schemes on sustainable basis. Also, the results of the study would add to the existing stock of knowledge on irrigation that may important for researchers.

2 LITERATURE REVIEW

2.1 Irrigation system

Like all systems, irrigation systems are made up of several components or parts that interact with one another. Irrigation systems are equally complex with multiple interacting parts. According to Lemperiere et al, (2014); There are three main constituents of irrigation systems; irrigation scheme, on-farm management and organizations.

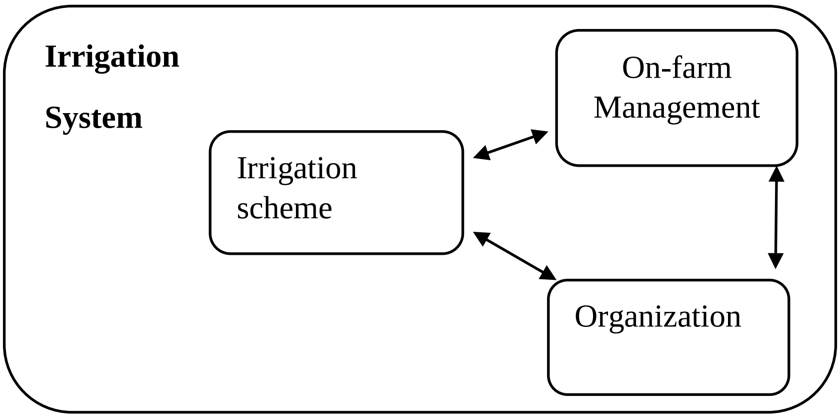

Figure 2-1:The three main constitutes of irrigation schemes (Lemperiere, P. et.al , 2014)

2.1.1 Irrigation scheme

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 (often at some distance from the cultivated fields) to the fields, an infrastructure consisting of canals and regulation structures is necessary. An organizational structure is needed to execute the necessary tasks to manage and control the infrastructures (Ertsen, 2005). Small scale schemes, including their main water supply infrastructure, might be managed entirely by a WUA. The objective is greater user commitment, which can lead to more efficient use of the resources by helping to overcome many of the problems that public irrigation systems face, such as inequitable water distribution, corruption, inefficiency, drainage and poor operation and maintenance.

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.

2.1.2 On-farm management

Inefficient water uses 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. Those are 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 user's organization and Field level or on-farm distribution and application system managed by the individual farmer.

2.1.3 Institutions/Organizations/

According to Blank et al., (2002), few among the institutional arrangements which facilitate collective action in small-scale irrigation systems, and which includes Land tenure and water rights (formal and informal) in the irrigation systems, Users organizations and their by-laws and enforcement characteristics and Stakeholders and their Relationships in irrigation management (concerned government agencies, farmer's organizations and users).

According to Tafa (2002), analysis of existing situation indicates that if irrigation is to play a crucial role as engine for further expansion of agricultural production, the management and organization of irrigation systems, including their institutional implications, must be substantially improved.

2.2 Irrigation water control and 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 farmer's field and drainage of excess water from farmer's 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. It also includes various steps of investigations, planning, designing, construction, operation, maintenance and rehabilitation of irrigation and drainage facilities.

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

2.3 Irrigation water management and development plan of Ethiopia

Almost all the irrigation schemes initiated in the past in Ethiopia have been functioning below anticipated targets (Habtamu, 1990). Hundreds of reservoirs have been constructed but are not yet effectively used for irrigation (FAO, 1995).

Co-SAERAR (1999) stated that irrigation development in the country perform poorly because of lack of technology or technical deficiencies, faulty assumptions and practices related to the operation and maintenance and overall management of the system.

Under the current agriculture led economic development plan of the country, focus is being made on irrigation development by harnessing the natural resources. The potential irrigable area of Ethiopia is estimated to be about 3.73 million hectares (WAPCOS, 1990) out of which to date only 197,250 ha (1998) have been developed for irrigation, including the areas under small scale irrigation. According to the estimates made in the year 1991, the areas under small scale comprised of 6400 ha while the areas under medium and large scale were 112,105 ha. These areas account only 3.4 percent of the total food crop production of the country. If the country is to curtail the recurrent food deficit caused by draught and persisting population pressure, relevant measures have to be taken to improve the productivity of rainfed as well as irrigated agriculture (MoWR, 2002). The current development has been focusing on the development of small scale irrigation.

To address the problem of food security, and to meet the demands of food and fiber requirement, the country has prepared a fifteen-year plan to develop additional 273,829 ha of land, which is an increase of 135 percent of the currently irrigated land. A country wide total area of 1,057 small scale schemes having a combined area of 80,667 ha have been planned for development by various stakeholders during the short and medium planning horizons (MoWR, 2002).

The attempt by the government to enhance the participation of individual peasants in small scale irrigation development had been considered earlier throughout the 1970s and 1980s; but the results were below expectations. Though the Government has been providing irrigation infrastructure free of charge and the infrastructure development progressed well but putting the schemes into production at optimum level was very disappointing, and in some instances only 10 % of the developed areas were put into production (Fekadu, et al, 2000).

2.4 Performance evaluation of irrigation Project

2.4.1 Importance of performance evaluation

The performance of any irrigation system is the degree to which it achieves the desired objectives. Hence, evaluations are useful through a number of tools in order to improve the overall management of the system and enhance efficiency. According to Molden*et al*. (1998) the principal objective of evaluating the performance of irrigation systems is to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency. Moreover, performance is assessed for a variety of reasons: to improve system operations; to assess progress against strategic goals; as an integral part of performance-oriented management, to assess the general health of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance; to compare the performance of a system with others or with the same system overtime.

Regarding the different approaches of soliciting evaluation data, it can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year. The other means of collecting the evaluation data is through conducting assessment research. The types of performance measures (indicators) to be chosen depend on the purpose of the performance assessment activity (Molden *et al*., 1998). With these indicators the amount of deviation between the actual values against the intended are evaluated.

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).

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 assessment 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.

2.4.2 Performance indicator

Indicators are used to measure performance. An indicator describes the level of actual achievements in respect of objectives of irrigation. It is useful to consider an irrigation system in the context of nested systems to describe different types and uses of performance indicators (Small and Svendsen, 1992). An irrigation system is nested within an irrigated agricultural system, which in turn can be considered part of an agricultural economic system. For each of the systems, process, output, and impact measures can be considered.

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). In connection with main system performance, the authors concluded that the services provided by the system and the appropriate performance standards are greatly influenced by the design of that system. 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.

Bos, (1997) summarizes the performance indicators currently used in the Research Program on Irrigation Performance (RPIP). Within this program field data are measured and collected to quantify and test about 40 multi-disciplinary performance indicators. These indicators cover water delivery, water use efficiency, maintenance, sustainability of irrigation, environmental aspects, socio-economic and management. He also noted that it is not recommended to use all described indicators under all circumstances.

2.4.2.1 properties of performance indicator

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

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

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

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

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

Ease of use and cost effectiveness: Particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment, and commitment of human resources, should be well within the agency's resources. Most authors propose to use different indicators and different methodologies or tools to measure the same indicators (Bos et al., 1994). But this causes much confusion in evaluation. To avoid this, studies recently categorized indicators into two groups to evaluate irrigation systems.

2.4.2.2 Process performance indicator

Process measures refer to the processes internal to the system that lead to the ultimate output, whereas output measures describe the quality and quantity of the outputs where they become available to the next higher system (Molden et al., 1998).

According to (Molden et al., 1998), much of the work to date in irrigation performance assessment has been focused on internal processes of irrigation systems. Many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated; and cropping patterns.

(Kloezen and Garces-Restrepo, 1998) had reviewed different literatures and summarizes that process indicators help system managers to monitor the quality of daily and seasonal operational performance but do not allow to assess the importance of irrigation in a given system, at different system levels, in a given season, and with a specific water source relative to other systems, levels, seasons, or irrigation sources.

A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of system management, and performance measures tell how well the system is performing relative to these targets. Generally, process indicators are used to assess actual irrigation performance relative to system-specific management goals and operational targets.

2.4.2.3 The principal terms of performance indicator

2.4.2.4 Internal process 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).

2.4.2.4.1 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.

In Tanzania, a survey of the efficiency of improved and unimproved small-scale irrigation schemes indicated that the conveyance efficiency for the main canals and the field canals (unlined) were 84 and 65% during the dry season and 85 and 74% during the wet season respectively. 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).

2.4.2.4.2 Application efficiency

Depending on the type of the source, water is diverted, or pumped to a canal or pipe for conveyance to the farm for distribution and finally for application to the crops in the field. When water is diverted into any water application system such as furrows, part of the water infiltrates into the soil for consumptive use by the crop, while the rest is lost as deep percolation and as runoff. The efficiency terms determine these components and compare them with the volume of water actually applied to the field is regarded as application efficiency. The term is an indication of the effectiveness of the system in reducing losses during an irrigation event (Walter, and Berisavijevic, 1991).

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).

The level of irrigation efficiencies under which irrigation projects operate vary according to the efficiency of design of the system and its quality of operation. The availability of water for irrigation also influences the level of efficiency; as under water shortage conditions farmers attempt to reduce water losses. Modern farms under good management can achieve better management as evidenced from 70 and 93% application and distribution efficiencies respectively obtained for the modern Amibara Project, recorded for 250 m furrows using stream flows varying from 2.13 to 3.5 l s-1 on Vertisols and alluvial soils (Kandiah, 1981).

The irrigation efficiencies vary in accordance with the type of surface irrigation. Walters and Berisavijevic (1991) found that sprinkler irrigation had the highest Ea (70%) while basin irrigation of rice had the lowest (30%). Wild flooding was also low (45%). For non-rice crops, such as dry food crops, the authors reported that the figures were not significantly different from each other (basins 54, furrows 55 and borders 58%).

2.4.2.4.3 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 Er 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 will reflect the degree of soil moisture stress. Usually, under-irrigation in high probability rainfall areas is a good practice to conserve water but the degree of under-irrigation is a difficult question to answer at the farm level (Walker, 1989). Adequacy has significant impact on the crop yields and thus on the economic return on water use. In an experiment, Raghuwanshi and Wallender (1998) found that the maximum return to water was achieved with irrigation adequacies of 63, 59, 54, 49 and 50%, for irrigation intervals of 10, 12, 14, 18, and 21 days respectively.

An irrigation interval of 10 days with 63% adequacy gave the global maximum return to water. However, the Natural Resource Conservation Service of UK recommends irrigation adequacy for homogeneous soil condition to be 87.5% (Raghuwanshi and Wal1ender, 1998).

2.4.2.4.4 Deep percolation

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 groundwater (Smedema and Rycroft, 1983). Higher DPR values are indications of over irrigation. 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).

2.4.2.4.5 Distribution efficiency

To fully express the efficiency of an irrigation system, the uniformity of the water applied need to be evaluated. Irrigation water needs to be applied uniformly in a field in order to achieve uniform crop growth. In practice, however, perfect uniformity of application is not possible. The common measure of uniformity of irrigation is coefficient of uniformity which is expressed as the deviation of infiltrated depth of water from mean depth of infiltrated water in the field.

Distribution uniformity is closely related with the advance ratio (AR), the ratio between the advance time and the time of irrigation. Large advance ratio and low distribution uniformity indicate too long a furrow or too small initial stream. It also indicates too small management allowed deficiency (MAD), or too large furrow spacing (Jensen, 1983). Infiltration, which is the movement of water into the soil, is an important factor affecting surface irrigation in that it determines the time the soil should be in contact with water (the intake opportunity time or the contact time). It also determines the rate at which water has to be applied to the fields, thereby controlling the advance rate of the overland flow and avoiding excessive deep percolation or excessive runoff. The infiltration or intake rate is defined as the rate at which water enters into the soil, usually expressed in mm hr-1 (Savva and Frenken, 2002).

2.4.2.4.6 Overall 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).

2.4.2.5 External performance indicator

External performance indicators evaluate irrigation systems based on relative comparison of absolute values, rather than being referenced to standards or target. 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 include:

2.4.2.5.1 Economic performance indicator

The International Water Management Institute (IWMI) developed a set of comparative performance indicators with the purpose of the economic assessment of irrigation performance (Molden et. al., 1998). In these indicators, water input-yield relationships are mainly used. These indicators allow a comparison of the performance of fundamentally different systems by standardizing the gross value of agricultural production. The standardized gross value of production (SGVP) per unit of water consumed is significant especially for areas where water scarcity exists, while output per unit of commanded or cropped area is more important for areas where the land is regarded as a limited source.

2.4.2.5.2 Financial indicator

Financial self-sufficiency indicates the ratio of revenue from the irrigation to the expenditure for operation and maintenance. It shows the compensation ratio of management and maintenance costs for irrigation system based on the income obtained from the irrigation. This in other words implies the sustainability of the schemes, and perception of the farmers towards the irrigation scheme. Whereas gross return on investment considered the production and the total cost of infrastructure for the scheme.

3 METHODOLOGY

3.1 Study area/setting

Upper Ashare irrigation project is found in: -

Zone – Awi administrative zone, Woreda – Dangila & South Achefer woreda, Kebele – East Zelesa, Ligaba and YebodenSite specific name (Got) – Asterio & Karnuari, Latitude (weir site) – 1244089 UTM, Longitude (weir site) – 274200.28 UTM and Altitude (weir site) – 2099.00m asl.

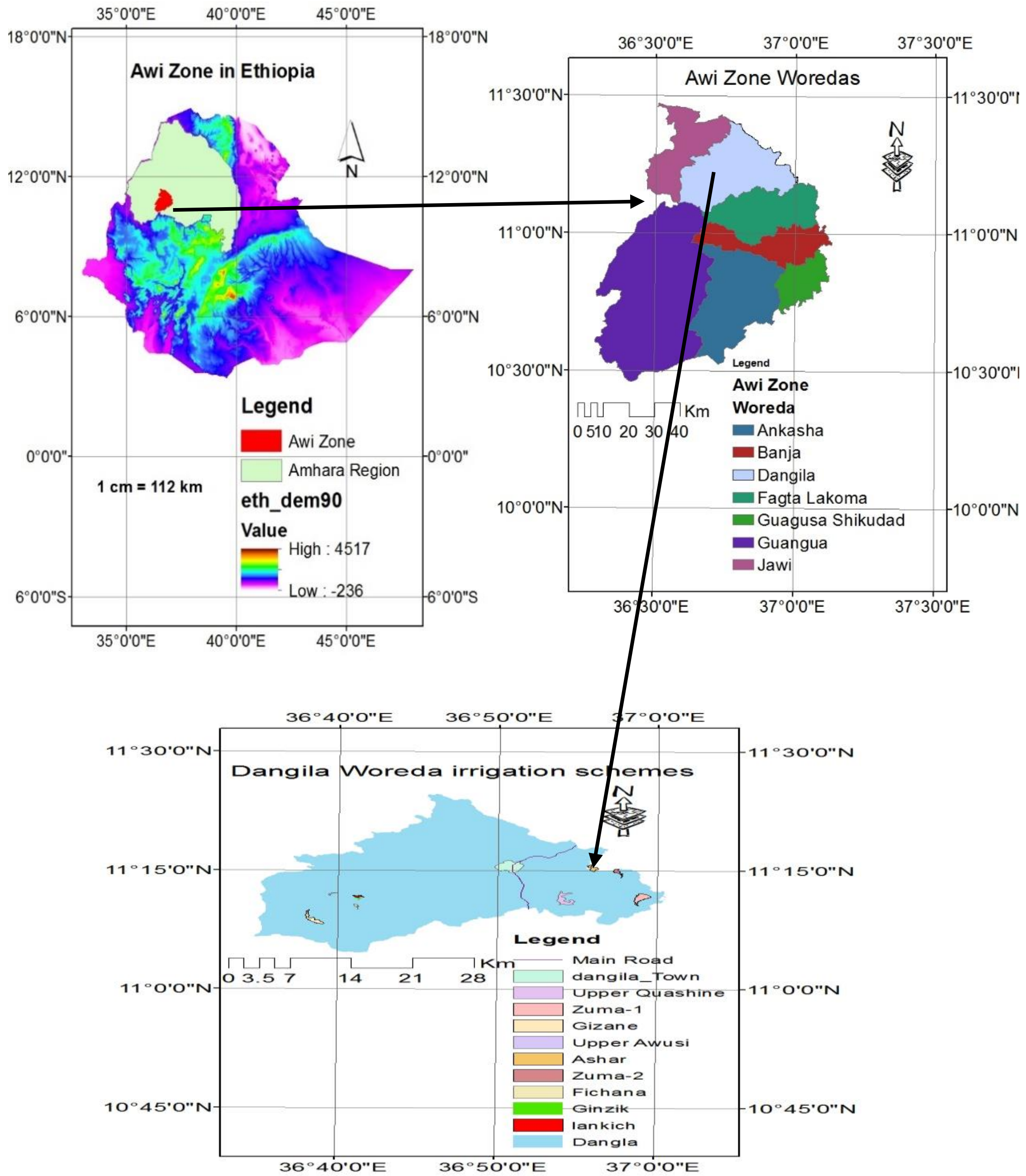

Figure 3-1:Study Area

3.2 Accessibility

Upper Ashare irrigation project head work site is found in Dangila woreda, in Awi Zone of Amhara Region. The project site is 10km from the woreda town Dangila, where it can be accessed through all-weather gravel road taking from Dangila to Afessa.

3.3 Study Design

Both experimental and descriptive study design were used. A study design/frame is the process that guides researchers on how to collect, analyze and interpret observations. Therefore, the objective of the research was achieved in accordance with the methodology outlined below.

3.4 Population

The parameter such as the soil characteristics, canal discharge measurement, the furrow geometry, slope and infiltration rate required to determine performance efficiency indices of Asher irrigation project were served as a population for the study.

3.5 Sample size

In order to evaluate farmers' perceptions about scheme performance initially the target schemes need to be stratified. The stratification was carried out based on relative location of respondents to irrigation schemes at head, middle and tail users. And respondents were selected through stratified systematic random sampling techniques from HH beneficiaries list. Depending up on the size of scheme 5-10 farm HH were selected in each of the strata for detailed investigations.

3.6 Study variable

The study variables assessed in this research are both independent and dependent variables.

Independent variable: - canals discharge measurement, dimensions, the soil characteristics, the furrow geometry and slopes, as well as infiltration rates.

Dependent variable: - Performance efficiency indices such as conveyance, application, storage, distribution uniformity and overall efficiencies along with the water productivity in terms of water use efficiency.

3.7 Climate

According to the Traditional Ethiopian Agro-Ecological Zones classification, by taking the amount of mean annual rainfall, mean air temperature and elevation of the area into considerations, the project area is said to be found in Wina dega agro-ecological zone.

3.7.1 Rain fall

The proposed command area has unimodal rainfall pattern; the main rainy season is summer, locally called Meher/Kiremt, which extends from June to September. The mean annual rainfall that the project area received is 1600.6 mm. Generally, the rainfall of the project area i characterized by its high variability both in amount and distribution. Meher or Kiremt rainfall is largely received in the months of, mid-June, July and August. Had it been well distributed throughout the growing season the amount of rainfall may have been sufficient for the growth of crops.

3.7.2 Temperature

Optimum temperature plays an important role on the growth period and the production of crops. In the project area the mean daily maximum air temperature ranges between 21.8 ^{0}c (July) and 28.4 ^{0}c (march); the mean daily minimum air temperature ranges between 4.8 ^{0}c (January) and 12.0 ^{0}c (June and July) the annual mean maximum air temperature of the area is 25.2 ^{0}c and minimum air temperature is 9.3 ^{0}c.

3.7.3 Sun Shine, Relative Humidity and Wind Speed

The sunshine hours' duration of the project area ranges from 4.15 (July) to 9.01 (February). Relative humidity (RH) in the project area the lowest 26% (March) to the highest 82% (July) and the mean relative humidity is 59%. The wind speed in the area ranges from 57 km/day (November) to 103 km/day (may) which is low then not damage the crops.

3.8 Component of head work

A Head Regulator structure is provided to facilitate the diversion and regulation of water from the river into the main canal. The river water thus diverted into the canal system is utilized to meet the water demand for irrigation as well as for other needs like domestic needs of population settled in and around the command area and/ or for the needs of livestock in the area.

The essential components of head works are:

- Weir length $32m$
- Design discharge 331m^3/s

3.9 Proposed Cropping Pattern and Crop Calendar

The Cropping pattern that has been plotted has to be used to calculate the irrigation water requirements during the cropping year. The major criteria to recommend this project cropping patterns are:

There is no too much of over lapping various pre-sowing and post harvesting operation, Aiming at efficient and more productive occupation of the available labor force during the year, The length of growing period (LGP) of the proposed crops and farmers' preferences, Contribution of crop rotation practices in breaking the life cycle of crop diseases, insect pests and parasitic weeds causing yield loss in mono-cropping practices and Inclusion of a leguminous crop in the crop rotation system to maintain soil nitrogen status for nitrogen fixation by the legumes.

In determining the proposed crops calendar (sowing and harvesting time, etc.), care has been taken in that there is no over lapping of pre-sowing and post-harvesting operations, beginning and ending of Kiremt rain season, belg rainfall and flood occurrence season, staggered planting, temperature suitability, and harvesting during dry and/or warm periods as far as possible.

The proposed cropping pattern and crop calendar have the following advantages:

It minimizes the risks of monoculture, guarantees annual incomes to a certain level, allows good employment and occupation of the available labor forces throughout the year, Reduce soil erosion through effective and continuous soil cover and production of animal feeds from crop residues.

Table 3.1 Proposed cropping pattern and calendar for dry season

Crop	**Area (ha)**	**Area (%)**	**Land preparation**	**Planting**	**Weeding**	**Harvesting**
Onion	17.71	23	Nov- Dec	20-Dec	Jan- Feb	Apr
Tomato	13.09	17	Nov	25-Dec	Feb-Mar	May
Potato	32.34	42	Oct- Nov	15-Dec	Feb-Apr	Apr- May
Cabbage	13.86	18	Nov	21-Dec	Feb- Mar	Apr-May
Total	**77**	**100**				

Source: Ligaba Kebele Agriculture and Rural Development Office, 2014.

For Ashar small scale irrigation project the net command area is 77 ha. A 200% cropping intensity has proposed for the project area in a way to have double cropping system. Means the whole command area can be cultivated twice in a year. Thus, a higher cropping intensity could be adopted for the project area for maximum utilization of land and water resources.

3.10 Data collection

The methodology used during the study were collection of primary data during the field work and supplemental data and necessary information were collected from previous study documents. And also crops produced in the irrigation scheme and the cropping pattern data were collected from irrigation scheme management unit at the site.

Data collection included both interviews and on-site observation and measurement. Those agro-meteorological data assessed were gather from office of meteorological station. The data were daily data and the rest were used from previous study document. The specific tasks included in the data collection works are presented as follows.

3.10.1 Primary data collection

Field assessment were carried out to see the situation of the scheme and collect data on the performance condition of the scheme. Information on the existing problems were recorded and the extent of investigation work decided based on the encountered problems.

Specifically, it is required to conduct: Field measurements and observations include field topography and configurations, irrigation delivery and inventory of structures, irrigation phases and field irrigation method, Interview of technical experts and Collection of soil samples.

3.10.2 Secondary data collection

Secondary data were collected from different sources, published and unpublished documents of respective offices and departments, related journals and books. Climatic data of the nearest station were collected from the National Meteorological Station and others.

3.10.3 Field Layout, Crop Selection and Experimentation

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

3.11 Data analysis method

- For crop water demand: The FAO's computer program CROPWAT8 package were utilized to calculate the crop water requirements.
- Laboratory; for determination of soil texture and moisture content parameters.
- Performance evaluation were computed based on the performance indicators listed below:

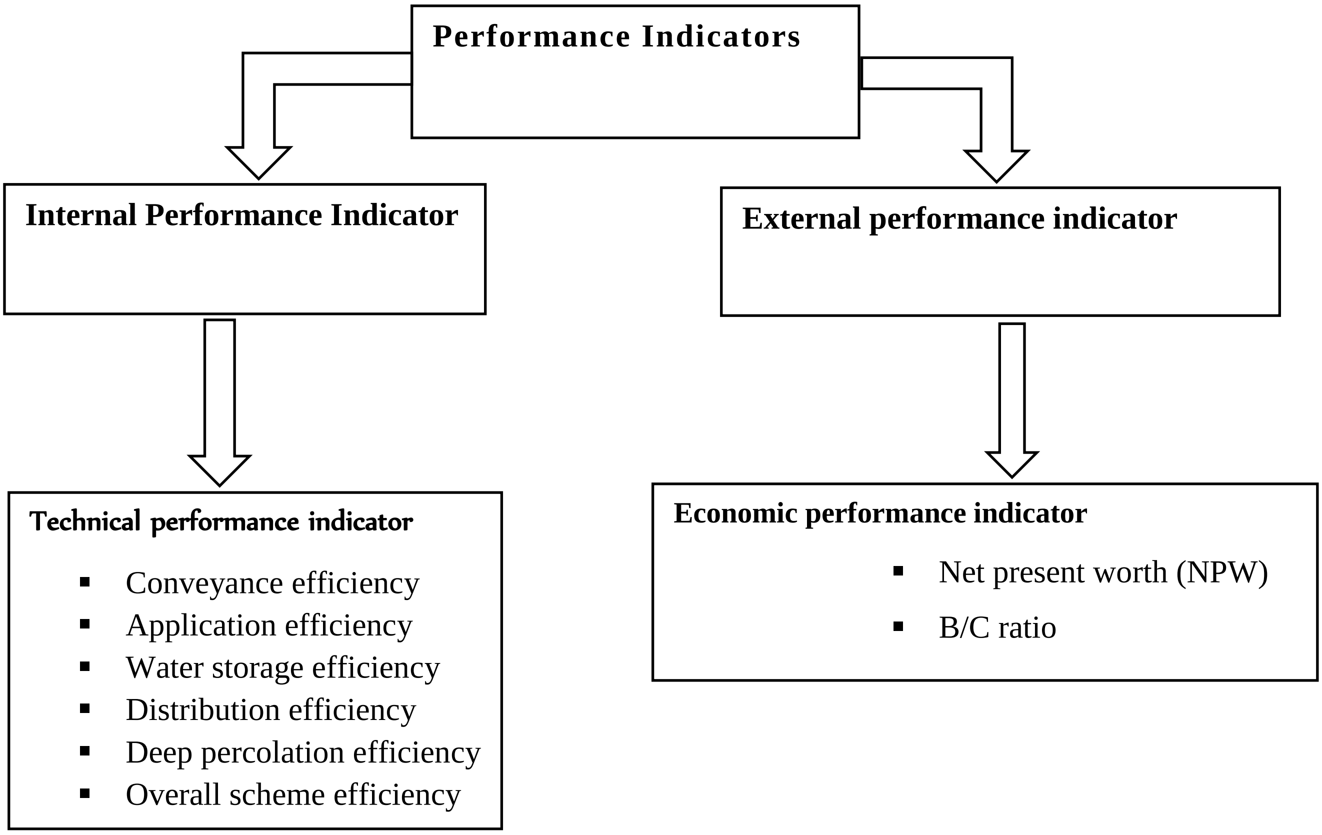

Figure 3.2 Framework for Performance Indicator

3.11.1 Scheme characterization

Characterization of the scheme was done by looking into the secondary information from design documents, field observation and canal measurements. Main and branch canals were described in terms of their discharge, canal dimensions, and length of flow and functionality of the scheme elements as well as analysis of number of civil works completed as per the design or not.

Characterization of Asher Irrigation Project is mostly resource characterization such as water and soil resources. The Water distribution and management system and the existing conditions of constructed structures were also assessed. Performance evaluation was carried out using different resource characterization and efficiency indices. The parameters required to determine the efficiency indices are the soil characteristics, the furrow geometry and slopes, as well as infiltration rates.

3.11.2 Technical performance indictors analysis

Technical performance evaluation analysis was conducted using technical efficiencies indicators. The technical evaluations were made for the following indicators; namely, conveyance efficiency, application efficiency, distribution uniformity, water storage efficiency and overall scheme efficiency. For this purpose, a total of nine farmers‟ fields were selected from irrigation scheme, i.e. from the head (H); from the middle (M) and from the tail (T) end water users of each irrigation scheme.

3.11.2.1 Conveyance efficiency estimation

The conveyance efficiency of the scheme was computed by taking discharges measurement at different points. The measurements were taken at a point of diversion (pump) and at the initial and final points of secondary, tertiary and field canals. It was computed as follows (Ramulu, 1998):

$$E_c = \frac{W_f}{W_s} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1a$$

The conveyance efficiency was calculated by using equation:

$$E_c = E_m \times E_s \times E_t \times E_f \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1b$$

Where, E_c is water conveyance efficiency (%), E_m is conveyance efficiency of main canal (%), E_s is conveyance efficiency of secondary canal (%), E_t is conveyance efficiency of tertiary canal (%), E_f is conveyance efficiency of field canal (%), W_s is volume of water diverted from the source (m^3) and W_f is volume of water applied to the field (m^3).

3.11.2.2 Application efficiency estimation

The application efficiency was computed as the ratio of moisture added to the soil profile due to irrigation to the total water supplied to the farm or the ratio of moisture retained due to irrigation with total water added to the field. In this particular research soil samples were collected from different fields at different depths (0 – 40cm and 40 – 80 cm) and the amount of water stored in the root zone determined by gravimetric method. Application efficiency was computed as follows (Ramulu, 1998):

$$Ea = \frac{Zr}{D} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where, Ea is application efficiency (%), Zr is average depth of water applied to the root zone as storage (mm) and D is average depth of water applied to the field (mm)

The depth of water stored in the root zone of selected field was determined from the soil moisture content before and a day after irrigation by gravimetric method. The depth of Water applied to the field was estimated by dividing the average total amount of water applied to the field by the area irrigated. The depth of water retained in root zone was calculated using equation (Michel, 2008)

$$d = \sum_{i=1}^{n} \frac{(\mathrm{Mafi} - \mathrm{Mbi})}{100} * \mathrm{Ai} * \mathrm{Di} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 3.3$$

Where:

d is depth of water retained into root zone of the soil (cm),

M_{afi} and M_{bi} are moisture contents in the i^{th} layer of the soil after and before irrigation (% weight basis),

A_i is bulk density of the soil in the i^{th} layer,

D_i is depth of the soil i^{th} soil layer within the root zone (cm) and n is number of layers in the root zone.

3.11.2.3 Water storage efficiency estimation

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 actually applied to the field. Due to spatial variability of the term it was lately replaced by another term, the uniformity index. The spatial uniformity of irrigation of water application provides an indication of adequacy of storage over the area. Storage efficiency was computed using the following relation (Ramulu, 1998):

$$\mathrm{Er} = \frac{D_{sr}}{Wn} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 3.4$$

Where, Er is storage efficiency (%), Dsr is water stored in root zone during irrigation (mm) and Wn is water desired to store in the root zone (mm).

3.11.2.3 Distribution uniformity estimation

Distribution uniformity was measured using the distribution uniformity index as proposed by James (1988). Also, distribution uniformity was determined by recording advance time and recession time at equal points of the selected furrows. The depth of water infiltrated during the opportunity time were derived from measurement of the infiltration rate of the soil, which was determined using double ring infiltrometer. The irrigation distribution uniformity was computed using the following formula:

$$Ed = \frac{Zmin}{Zav} * 100 \ldots\ldots\ldots 3.5$$

Where, Ed is distribution uniformity (%), Zmin is the minimum depth infiltrated at the ith point, in (mm) Zav is the mean depth infiltrated in (mm).

3.11.2.4 Determination of deep percolation

The runoff ratio is normally 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):

$$DPR = 100 - Ea - RR \ldots\ldots\ldots 3.6$$

Where, DPR is deep percolation ratio (%), Ea is application efficiency and RR is runoff ratio.

3.11.2.5 Determination of overall scheme efficiency

Finally, the overall scheme efficiency was calculated as the product of conveyance and application efficiency. It was computed using the following formula (Ramulu 1998):

$$Ep = Ec \; x \; Ea \ldots\ldots\ldots 3.7$$

Where, Ep is overall scheme efficiency (%), Ec is conveyance efficiency (%) and Ea is application efficiency (%).

3.11.3 Economic analysis

An economic efficiency analysis is a systematic way to compare yield, which would be produced with the total cost for the production. Two principal value measurement parameters were used in this analysis. To determine the total net contribution (net benefits) of a project to farmers, the net present worth (NPW) was used to provide a systematic ranking of alternatives and it was computed as:

$$\mathrm{NPW} = \sum [(\mathrm{Bt} - \mathrm{Ct})/(1 + \mathrm{r})^{\mathrm{t}}] \ldots\ldots\ldots 3.8$$

Where, NPW = the net present worth

Bt and Ct = benefit and cost in a year respectively, and

r=social discount rate.

To compare the benefits to costs, the B/c ratio formula was used as:

$$B/C\ ratio\ = \sum[Bt/(1+r)^t]/\sum[Ct/(1+r)^t] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 3.9$$

If B/C ratio is more than 1, the present value of benefit is greater than the present value of costs and project is economically efficient use of resources, assuming that there is no lower-cost means for achieving the benefits.

3.12 Crop water requirement

Crop water requirement is defined as the total water needed for evapotranspiration from planting to harvest for a given crop in a specific climatic regime when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Water is needed mainly to meet the demands of evaporation, transpiration and metabolic activities of the plant. The most important and initial step for planning, designing and implementation of irrigation projects is the determination of crop water requirements.

The growth and yield of any crop is related to the amount of water used. The variable amount of water contained in a soil and its energy state are important factors affecting growth of plants. The accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapotranspiration (Nuha and Henery, 2000).

Preplant irrigation is generally applied to increase the soil moisture content to field capacity. This facilitates germination of weed seeds before planting. However, some farmers, such as those at Dangila woreda are not in favor of this practice as they say it affects soil structure. Thus, preplant irrigation was not intentionally applied as part of the experiment other than that carried out for performance evaluation purposes. The soil had to be replowed and irrigated for planting of seedlings as it was too compacted. However, research showed that pre-plant irrigation did not contribute to storage efficiency and to increasing crop yields (Stone, et al, 1996).

3.12.1 Evapotranspiration

The main component of crop water requirement is evapotranspiration. The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration is referred to as evapotranspiration (ET). Evapotranspiration can also be defined as the total movement of water vapor in to the air, from the land which supports plants life and transpiration from plants. The Reference crop evapotranspiration (ETo) being defined as "the rate of evapotranspiration from a large area, covered by green grass, 8 to 15 cm tall green grass cover of uniform height, grows actively, completely shading the ground and not short of water. Whereas crop evapotranspiration(ETC) under standard condition is the evaporation from disease free, well fertilized crops, grown in large fields, under optimal soil water conditions, and achieving full production under the given climatic conditions (FAO,2000).

The method adopted to compute crop evapotranspiration (ETc) is Penman-Montheith method using a computer software program (CROPWAT 8.0), used for irrigation planning. Estimates that are more accurate can be obtained by using the Pen Man-Montheith method. The FAO Penman-Monteith approach is used to estimate ETo. The calculation of ETo rates requires use of cropwat 8.0 software. The software uses different climatic data as inputs to estimate ETo. The meteorological parameter and others to estimate ETo are mean temperature (Maximum and Minimum) (oc), mean relative humidity (%), wind speed at 2m height (km/day), sun shine hour duration (hr), latitude(m), longitude and altitude(o) of the station. The effect of crop characteristics on crop water requirements is accounted by the crop coefficient or Kc. Crop coefficient (Kc) varies with growth stages for each crop**.**

3.12.2 Yield data collection

To assess the overall impact of water distribution and performance parameters on yield, the yield of shallot was collected separately from head, middle and tail end plots. Water use efficiency was then calculated. Shallot was harvested by hand from the three ridges of all plots. The yield of the shallot was collected from three ridges by sampling from each selected plot. This was done dividing the ridges into three equal parts along its length. Then yield was collected from each plot in the fields and weighed. The total yield obtained from the test plot was also measured

4 RESULTS AND DESCUSSION

4.1 Surface Characteristics of the project area

Concerning the surface characteristics (stoniness, rock out crops, water logging and flooding, etc) of the command area, it has estimated that the command area has no stones or very few stones in pocket spots (<0.5% area cover), and no rock out crops. This situation is suitable for full capacity of crop seedling.

4.1.1 Water resource

In the project area, there are only four perennial rivers (zuma, abay, ashar, guder,) beside to this; there are also eight perennial springs (aymerga, godgadet, ashenferet, shelant, arbamench, seto, meskel dar, mukechet). Traditional irrigation system is being practiced in the project site. Traditional irrigation systems are started since long years ago and still constructing traditional structures on these rivers.

4.1.2 Command area

The topography of the area is characterized by partly gentle slope and flat area. The topographical surveys have been conducted with the help of Total Station Method and results have been fed into computer from which topographical maps have been generated with 0.5m contour interval, 1: 1,000 horizontals and 1:100 vertical scales.

The final size of the command area of the project is determined based on the result of the topographic survey, hydrological study, and soil survey and land evaluation study results. Accordingly, the survey has been conducted for entire command area measuring approximately 180Ha. After deducting non-suitable area like rock exposures, gully and stream/river, area of unsuitable soil and residential areas, net irrigable area of 77.75 ha has been obtained.

4.1.3 Soil characterization

Physical analysis and analysis for different chemical properties, bulk density of soil and moisture content at field capacity and permanent wilting point were determined at Amhara Design and Supervision Works enterprise soil laboratory. The soil texture was determined using sieve analysis. The organic matter content was derived by multiplying the organic carbon content by a factor of 1.724, the ratio between humus and organic matter (Baruah and Barthakur, 1986). The bulk density of the soil was determined by dividing the weight of the oven dried core samples for 24 hrs at 104 ^{o}c, by the volume of the sample obtained from the volume of the core sampler. Pressure plate apparatus was used to determine the moisture content of the soil samples at field capacity (FC), and permanent wilting point (PWP), by applying pressures at 0.33 and 15 bars respectively. The physical and chemical properties of the soils of the test plots are presented in Table 4.2

4.1.3.1 Soil physical characteristics

- **Topography:** Topography is an important factor for the planning of any irrigation project so long as it influences method of irrigation, drainage, erosion, costs of land development, mechanization, labor requirement and choice of crops. Topographically most of the cultivated lands of the project area are flat lands. In general, the command area lies from flat to level slope and the command area has more suitable for surface irrigation.
- **Vegetation:** From physical observation of the project site and Information collected from ligaba kebele agriculture and rural development office indicated that about 5.19% (69.75 ha) of the total area of the kebele is covered by forests. The major trees planted, and grown are Bahir zaf (eucalyptus globules), Girar (Acacia abyssinica), cheba (Acacia), Shinet (Myrica salicifolia),Sesa, Wanza (cordia africana),Yabesha Tid (Juniperus procera),Yeferenji Tid (Cupresus spp);and from bushes: Agam (Carissa edulis), Atat (Maytenus arbutifolia), Abalo (Terminalia brownie),Kega (Abyssinia rose), Chifrig, and also bushes such as Azo harege, Ayte harege (local) other domestic and forign species of trees are growen.
- **Soil:** From filed observations the soils of the command area were identified dominantly as red to brown colored soil. In addition to this, soils of the command area have no water logging characteristics during wet and dry season. This condition will be good for crops to be growing both in wet and when modern irrigation scheme commences. During the feasibility study, a composite surface (0-40cm) and subsurface (40-80cm) soil samples were collected from a representative place and analyzed for soil physical and chemical properties at Amhara Design and Supervision Works enterprise soil laboratory.

4.1.3.2 Soil chemical characteristics

- **Soil Reaction:** The pH of the soils in the study area ranges from 8.11 to 8.16, the majority being greater than 8. This indicates that the soils of the study area are predominantly alkaline and it is higher than the preferred pH range for most commercial crops. The higher pH value may inhibit availability of micronutrients. The possible options to the condition of the pH is either to select crops adapted to higher pH condition or apply acidifying fertilizer so as to lower the pH in the course of irrigation development.

- **Electrical conductivity (EC):** The electrical conductivity of a soil water solution is an indicator of the total soluble salts in the soil sample. EC values over 4 ds/m are considered as restrictive for yields of many crops; whereas values as low as 2 ds/cm restrict yields of most sensitive crops. Based on the soil lab result soils of the command area has EC values ranging from 0.16 to 0.19 ds/cm which indicates a non-saline effect on the selected crops.

Based on the laboratory the soil textural analysis of the project area is characterized as silt loam. The analysis of the soils results of the project area are presented in Table 4.1 and 4.2. The bulk density value ranges from 1.08 to 1.11 typical for the silt loam soils. The bulk density values of the soils at Asher irrigation schemes were low as per the bulk density rating of Jones *et al. (*2003) indicating that there was no compaction that could limit infiltration of water into and through the soil and root penetration. The Electrical conductivity of the solution extract (ECe) of the soil was also ranges from 0.16 to 0.19 ds m^{-1} indicating that the salinity and sodicity hazards are very low.

Table 4.1 soil textural analysis

Profile	Depth (cm)	Bulk Density gm cm^{-1}	Sand %	Clay %	Silt %	Textural Class
H	0-40	1.11	56.6	19.1	23.4	Silty loam
	40-80	1.08	51.3	18.0	26.1	Silty loam
M	0-40	1.10	54.4	19.8	24.3	Silty loam
	40-80	1.09	52.2	17.5	22.6	Silty loam
T	0-40	1.08	53.1	18.7	23.7	Silty loam
	40-80	1.10	51.7	17.2	25.4	Silty loam

Table 4.2 Physical and chemical properties of soils of test plots at Ashare farm

Soil characteristics	Soil depth (cm) H		Soil depth(cm) M		Soil depth(cm) T	
	0-40	40-80	0-40	40-80	0-40	40-80
pH - (H_2O)	8.11	8.13	8.13	8.14	8.12	8.15
pH - KCl	7.5	7.3	7.4	7.3	7.4	7.2
ECe ds/m^{-1}	0.16	0.17	0.16	0.18	0.17	0.19
Exch Na meq/ 100gm soil	0.43	0.52	0.41	0.44	0.44	0.49
Exch K (meq/100gm of soil)	1.72	1.50	1.76	1.61	1.73	1.58
Exch ca (meq/100gm of soil	22.3	27.8	22.1	28.0	22.5	27.7
Exch Mg (meq/100gm of soil	1.80	2.41	1.83	2.51	1.79	2.38
CEC (meq/100gm of soil)	27.4	39.0	27.1	38.7	27.7	39.3
Organic Carbon (%)	1.2	0.9	1.1	1.0	1.2	0.8
Available P (mg P_2O_5/kg soil)	26.1	11.3	24.5	10.1	27.3	11.6
Organic matter	2.06	1.55	1.89	1.72	2.06	1.37
Bulk Density (gm/cm^3)	1.11	1.08	1.10	1.09	1.08	1.10
Field Capacity (in% at 0.1 Bar)	32.43	33.12	31.73	29.98	32.58	31.08

Wilting Point (in% at 15 Bar)	10.72	12.01	10.45	11.98	11.11	10.79

4.2 Canal section

Two types of canal sections are adopted in Ashar project

- Trapezoidal canal section and
- Rectangular canal section

The total length of main canals is 2592 m out of which only 573 m is proposed to be masonry lined canal. The rest of the main canal lengths are proposed to be earthen canals. The secondary, tertiary and field canals are all proposed to be earthen trapezoidal canals.

All earthen canals are designed as trapezoidal section having side slope of m = 1, and free board 0.325m for main canal, and m = 1.0 for secondary canals &tertiary canals and free board of 0.3m for all. For earthen/soil surface Roughness co-efficient of N = 0.025 is adopted, but the longitudinal slope varies from canal to canal based on the slope of topographic were the alignments of canals pass.

The irrigation system proposed comprises the canal network on both left and right side having main canals. On the right side the system comprises of one main canal, two secondary canals, four tertiary canals and 24 field canals which total irrigates an area of 51.78 ha. In addition, on the left side the system comprises of one main canal, one secondary canal, two tertiary canals and 12 field canals.

Figure 4.1 head work

4.2.1 Main canal

The layout of main canal is the most important and vital component of the entire planning work, that call for most careful consideration of all the factors governing the alignment: topography, natural drainage pattern etc. The main canal is aligned nearly along the contour lines to minimize loose of head. The total length of the main canal is 1.98 km

4.2.2 Secondary canal

There are totally three secondary canals (on the right side RSC1 & RSC2, on the left side LSC1) which are aligned across the contour and partly across the contour. The total length of all secondary canals is 0.53 km.

4.2.3 Tertiary canal

The entire command area of the project is planned to be irrigated usingo, the tertiary canals that off take directly from the secondary canals and supplies irrigation water to field canals. There are 6 tertiary canals that off take from their corresponding secondary canals and run nearly as a contour canal. The total length of tertiary canals is nearly 5 km. The average length of the tertiary canals is 0.83 km and depending on the shape of the tertiary unit, the average tertiary canal command 12ha of net irrigable land.

4.2.4 Field canal

The command area of each tertiary canal is further sub-divided into several segments by field canals, which supply water to the furrows. These canals are aligned across the contour. By considering the proposed crops, furrow method of irrigation has been adopted. Accordingly, irrigation water was applied to the farm through furrows. The average length of field canals is 180 meters. Irrigation water will be supplied to several furrows at a time, depending on the size of field canal that apply irrigation water. The total length of the field canals is estimated to be 5.1 km.

Figure 4.2 measuring conveyance efficiency on main canal of Asher irrigation scheme using current meter

4.2.5 Drainage system

The main canals of Ashar irrigation project crosses three gullies, one river (Zuma River) and one spring (Tekemshign Spring). Lateral inflows from streams and gullies intercepted by canals at five places and must be prevented from entering the canal. The right side of the main canal crosses river Zuma and Tekemshign Spring and the left side of the main canal crosses three gullies of different dimension at different chainage which requires taking measures to convey the flow of irrigation water for the proposed command area.

Figure 4.3 cross drainage structure

4.3 Performance evaluation

4.3.1 Technical performance indicators

4.3.1.1 Conveyance efficiency

The results of the conveyance efficiency evaluation revealed that this indicator varied within a farm at different points, between farms within a scheme and between schemes. Appendix Table 7 presents summary of the results of conveyance efficiency (Ec) for test plots of the three field locations (upstream, middle stream and downstream). The obtained values were 61.21%, 59.25% and 62.97% for upstream, middle stream and downstream users respectively. The conveyance efficiency of the downstream user is better than the both upstream and middle stream users. This is probably associated with main canals, secondary canals and tertiary canals management. The average conveyance efficiency values which indicate the amount of water lost during transportation of water from the diversion point or source to the field canal of Ashar irrigation schemes were found to be 61.38%. The details of conveyance efficiencies for selected fields in Ashar irrigation schemes are shown in Appendix Tables7 and the average conveyance efficiencies presented in Table 11.

4.3.1.2 Application efficiency

Water application efficiency provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. Appendix Table 8 presents summary of the results of application efficiency (Ea) for test plots of the three field locations (upstream, middle stream and downstream). The obtained values were 62.67%, 52.58% and 52.32% for upstream, middle stream and downstream users respectively. This indicates that the downstream irrigators are inefficient by applying excess water to their fields. Those irrigators, who are getting less access to water, were able to efficiently utilize what they have got even if the uniformity is poor.

In general, according to Michael (1997), water application efficiency decreases as the amount of water applied during number of irrigation event increases.

4.3.1.3 Water storage efficiency

Storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application. The water storage efficiencies (Er) computed by monitoring soil moisture before and after irrigations. The average results obtained were 52.99%, 51.99% and 52.93% for upstream, middle and downstream locations of the test plots respectively. The storage efficiency at upstream location of the test plot is slightly greater than both at middle and downstream location. In general, the storage efficiency of the schemes was very poor as compared to 63% storage efficiency usually found in typical furrow irrigation systems (Raghuwanshi and Wallender, 1998). This normally shows over irrigation of the field and this might be associated with the intention of the farmers on high return from high irrigation depth. The details of storage efficiency for selected fields and the average storage efficiency in schemes are shown in Appendix Tables 8.

4.3.1.4 Distribution uniformity

Distribution uniformity is used to express the variation in depths of application or supplied volumes. Distribution uniformity (DU) of the scheme was evaluated by monitoring the depth of water infiltrated into the root zone depth using soil moisture content. In this particular study the average results obtained were 88.63%, 87.92% and 91.47% for upstream, middle and downstream locations of the test plots respectively (Appendix Table 9).

The irrigation uniformities of schemes were very good, which may be due to the short furrow length commonly 15-meter, closed furrow ends and large stream flow. The irrigation uniformity figures observed in schemes of present study are much higher than the advanced furrow irrigation systems, which is 70% reported by Raghuwanshi and Wallender (1998) and the modern Amibara Project irrigation uniformity of 93% as reported by Kandiah (1981).

4.3.1.5 Deep percolation

Since the irrigation scheme considered in this study is blocked end furrows the main source of water loss was deep percolation. Higher deep percolation ratio values are indications of over irrigation. The deep percolation ratio calculated was 37.33%, 47.42% and 47.68% for upstream, middle stream and downstream test plots, respectively (Appendix Table 10). From this result the high deep percolation ratio was observed at the downstream and low at the upstream location of the test plot. The result also indicates that losses are in decreasing trend as the access of getting water are decreasing or upstream irrigators are irrigating with minimum loss as compared to downstream and middle irrigators.

4.3.1.6 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. The overall scheme efficiency calculated was 38.36%, 31.15% and 32.95% for upstream, middle stream and downstream test plots, respectively (Appendix Table 11). The result indicated that the middle stream irrigator was relatively poor as compared to upstream and downstream users. In the present study the average overall efficiencies of the irrigation schemes at Ashar were found to be 34.15%. The details of overall scheme efficiency of schemes were derived from the data shown in Appendix Tables 7 and 8 while the average overall irrigation scheme efficiencies of schemes are shown in Appendix Table 11.

4.3.1.7 Economic performance indicator

If B/C ratio is more than 1, the present value of benefit is greater than the present value of costs and project is economically efficient use of resources, assuming that there is no lower cost means for achieving the benefits.

The economic efficiency of the project was evaluated by comparing the benefits gained from the onion yield with the total cost of production as described before. The total net benefits of a project to farmers were determined by using the net present worth and computed using the above equation and tabulated in Table 4.5. The necessary cost data for onion production during the study period were collected from the irrigators at the plot level. The analyzed input cost breakdown and the total net benefit per unit of water applied results are tabulated in Tables. The present value of benefits and costs were determined by taking current interest rate 5% and since a project had long life age, the economic efficiency was predicted for 10 years of life.

Table 4.3 Crop budget for Onion production per hectare

S.N.	**ITEMS**	**Unit of Measurements**	**QT/UNIT**	**Field code**		
				H	**M**	**T**
1	**COST**					
1.1	**LABOUR**	**MD/ha**	-	175.0	175.0	175.0
-	Price	Birr/MD	40.0	7,000	7,000	7,000
1.2	Seed	kg/ha	-	4.00	4.0	4.0
-	Price	Birr/kg	1170.00	4,680	4,680	4,680
1.3	OXEN	OD/ha	-	14	14.0	14.0
-	Price	Birr/OD	90.00	1,260	1,260	1,260
1.4	DAP	qt/ha	-	2.00	2.00	2.00
-	Price	Birr/kg	1540.00	3,080	3,080	3,080
1.5	Insecticides	lit/ha	-	2.00	2.0	2.0
-	Price	Birr/lit	85.00	170	170	170
1.6	UREA	qt/ha	-	1.00	1.00	1.00
-	Price	Birr/qt	1270.00	1,270	1,270	1,270
1.7	Liming	kg/ha	-	-	-	-
-	Price	Birr/kg	150.00	-	-	-
1.8	Farm Implements	Lump sum/ha	-	1	1	1
-	Price	Birr/ha	980	980	980	980
1.9	Packing Materials 2	-	-	107	120	135
-	Price	Birr/Harvest	-	-	-	-
1.1	**land tax**	Ha	-	**1**	**1**	**1**
-	Price	(Birr/ha/season)	27.50	27.50	27.50	27.50

1.11	**Packing Materials1**	Sack	-	107	120	135
-	Price	Birr/piece	10	1,070	1,200	1,350
-	Sub Total	Birr/ha	-	19,538	19,668	19,818
1.12	**Miscellaneous costs**	%	5.0%	977	983	991
-	**Total Cost**	**-**	-	**20,514**	**20,651**	**20,808**
2	**Return**	**-**	-	-	-	-
2.1	**Yield (Main Crop)**	**Qt**	-	107.0	120.0	135.0
-	**Gross Return - Main**	**Birr/qt**	350.00	37,450	42,000	47,250
2.2	**Yield (by-product)**	**Qt**	-	-	-	-
-	**Gross Return-by-product**	**Birr/ha**	-	-	-	-
2.3	total gross return	Birr/ha	-	37,450	42,000	47,250
2.4	**Net Return**	**Birr/ha**	-	16,936	21,349	26,442

Note: - Labor cost includes costs for land preparation, planting, weeding, harvesting (uprooting) and transporting etc.

Table 4.4 Net present worth (NPW)

Field code	Gross benefit (birr/ha)	Total cost (birr/ha)	Net benefit (birr/ha)	$(1+r)^t$	NPW (birr)
H	37450	20514	16936	1.63	10390.18
M	42000	20651	21349	1.63	13097.55
T	47250	20808	26442	1.63	16222.09

Table 4.5 Economic efficiency

Field code	Gross benefit (birr/ha)	Total cost (birr/ha)	$(1+r)^t$	PV of benefit (birr/ha)	PV of cost (birr/ha)	B/C ratio
H	37450	20514	1.63	22975.46	12585.28	1.83
M	42000	20651	1.63	25766.87	12669.32	2.04
T	47250	20808	1.63	28987.73	12765.64	2.27

The benefit cost ratio was computed using equation given and the result was presented on the Table above. The benefit-cost ratio results observed for the three location users were 1.83, 2.04 and 2.27 for upstream, middle and tail users, respectively. The maximum economic efficiency was found in tail location irrigators (2.27) whereas the minimum economic efficiency was found in upstream location beneficiary (1.83) next to middle irrigators (2.04). This might be due to farmers in the tail fields applied water nearly equal to the water requirement of the crop as calculated by CROPWAT software program. In general, the analysis indicates that onion production in the scheme is economically efficient in terms of water use, since the benefit-cost ratio values of the three locations were more than 1.

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this study, an attempt was made to characterize and evaluate the performance of Ashar small scale irrigation schemes at South Achefer and Dangila District, Amhara Regional State of Ethiopia using technical and economic performance indicators.

The technical performance indicators computed were conveyance efficiency, application efficiency, storage efficiency, deep percolation ratio, distribution uniformity and overall efficiency.

From this study the following conclusions can be outlined.

- There is a room to improve performance of furrow irrigation system in the scheme through selection of appropriate flow rate and time of cutoff that would result in maximum or near maximum application and acceptable level of deep percolation loss.
- Low efficiencies were achieved and the irrigation water management at farmers' field level in the scheme was poor. This was due to the fact that the system permitted farmers to apply large volume of water to their fields combined with poor knowledge about the crop water requirements of the farmers.
- water logging problem had been observed due to over irrigation of water for some years in the upstream fields of the scheme. To combat these problems farmers were constructing traditional drainage structures to drain out excess water from the fields.
- Poor management system is also evidence on distributing this scarce resource to all beneficiary community.
- In general, it can be concluded that productivity of the cropping system can be improved by minimizing over- irrigation of the root zone and minimizing water losses due to deep percolation losses and applying water according to water requirement.

5.2 Recommendation

From the study, the following recommendations are forwarded for sustainable resource utilization.

- Equity distribution of irrigation water within and among farmers at different locations and avoid water logging problem at field due to poor water management, it is better to give intensive practical training to the farmers about farming system and economical application of water at the field.
- The efficiency of the farm could be improved through regular maintenance of the field canals and irrigation control facilities, using siphons for water abstraction into the field ditches or basins, and through avoiding breaching of canals.
- For minimization of conveyance loss in the canals and equity of water distribution among farmers at different location timely construction and design off-take structure should be done.
- The efficiency of the project needs improvement; therefore, the following measures can be taken:
- Preparation of extra drainage system is necessary for the scheme to avoid accumulation of excess water in the lower spots that leads to deep percolation loss.
- Regulation of field channels, waterways and weed growth in the unlined canals can improve canal conveyance efficiency
- Regular maintenance of cracks, holes, furrows damages and leaks in water control structures is simple and effective to improve irrigation efficiency
- The application efficiency can be improved by proper land leveling and grading which are the prerequisite for efficient water application.

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Appendices

Appendix Table 1. Average 23 years (1993 - 2015) of Meteorological and ETo data of the study area (dangila Station)

Country: Ethiopia Station: Dangila

Altitude: 2175m asl Latitude: 2.42 (North)

Longitude: 45.60 (East)

Month	Min Tem °c	Max Tem °c	Hum, %	Wind Km/day	Sunshine hours	Radiation $MJ/m^2/day$	ETo mm/day
Jan	4.8	26.2	46	74	8.96	22.0	3.95
Feb	6.5	27.8	42	82	9.01	22.9	4.38
Mar	8.6	28.4	26	94	8.12	22.2	4.59
Apr	10.7	28.2	42	98	8.21	21.8	4.53
May	11.9	26.3	54	103	7.45	20	4.07
June	12.0	23.6	75	93	5.97	17.2	3.25
July	12.0	21.8	81	88	4.15	14.7	2.76
Aug	11.9	22.0	82	87	4.25	15.5	2.90
Sept	11.1	23.3	79	74	6.10	18.8	3.43
Oct	10.0	24.0	72	63	6.58	19.3	3.51
Nov	7.4	24.9	61	57	8.18	21.4	3.69
Dec	5.2	25.6	53	63	8.69	21.5	3.71
Average	**9.3**	**25.2**	**59**	**81**	**7.1**	**19.7**	**3.73**

ETo is reference evapotranspiration

Appendix Table 2: Monthly rainfall data of Dangila station

Month	Rain, mm	Effective rain, mm
January	2.5	2.0
February	2.0	1.6
March	23.1	18.5
April	41.4	33.1
May	149.1	119.3
June	255.1	204.1
July	353.6	282.9
August	366.3	293.0
September	251.4	201.1
October	113.8	91.0
November	36.6	29.3
December	5.7	4.6
Total	**1600.6**	**1280.5**

Appendix Table 3 CROPWAT 8 output for onion water requirement

Month	Decade	Stage	Kc Coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	IR mm/day	IR mm/dec
Dec	3	Ini	0.70	2.65	18.6	0.3	2.61	18.2
Jan	1	Ini	0.70	2.71	27.1	1.0	2.61	26.1
Jan	2	In/De	0.71	2.80	28.0	0.8	2.71	27.1
Jan	3	Deve	0.76	3.11	34.3	0.7	3.05	33.5
Feb	1	Deve	0.85	3.59	35.9	0.2	3.56	35.6
Feb	2	Deve	0.93	4.06	40.6	0.0	4.06	40.6
Feb	3	Deve	1.00	4.45	35.6	1.6	4.25	34.0
Mar	1	De/Mi	1.05	4.74	47.4	4.2	4.32	43.2

Mar	2	Mid	1.07	4.89	48.9	6.0	4.29	42.9
Mar	3	Mi/Lt	0.96	4.38	48.2	7.8	3.67	42.4
Apr	1	Late	0.81	3.68	11.0	2.2	2.93	8.8
Total					**375.6**	**25.1**		**350.5**

Appendix Table 4 CROPWAT 8 output for potato water requirement

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	2	Init	0.6	1.99	12	0	12
Dec	3	Init	0.6	2.06	22.6	0	22.6
Jan	1	Deve	0.61	2.14	21.4	0	21.4
Jan	2	Deve	0.74	2.69	26.9	0	26.9
Jan	3	Deve	0.94	3.57	39.3	0	39.3
Feb	1	Mid	1.13	4.46	44.6	0	44.6
Feb	2	Mid	1.17	4.81	48.1	0	48.1
Feb	3	Mid	1.17	4.96	39.7	0.1	39.6
Mar	1	Late	1.17	5.1	51	0.4	50.6
Mar	2	Late	1.07	4.82	48.2	0.6	47.5
Mar	3	Late	0.91	4.16	45.8	2.3	43.5
Apr	1	Late	0.77	3.56	28.5	1.5	26.6
					428	4.9	422.7

Appendix Table 5 CROPWAT 8 output for cabbage water requirement

Month	Decade	Stage	Kc Coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	IR mm/day	IR mm/dec
Dec	3	Ini	0.70	2.65	5.3	0.1	2.61	5.2
Jan	1	Ini	0.70	2.71	27.1	1.0	2.61	26.1
Jan	2	Ini	0.70	2.76	27.6	0.8	2.68	26.8
Jan	3	In/De	0.71	2.92	32.1	0.7	2.85	31.4
Feb	1	Dev	0.77	3.27	32.7	0.2	3.25	32.5
Feb	2	Dev	0.86	3.78	37.8	0.0	3.78	37.8
Feb	3	Dev	0.95	4.21	33.7	1.6	4.00	32.0
Mar	1	De/Mi	1.02	4.62	46.2	4.2	4.20	42.0
Mar	2	Mid	1.06	4.88	48.8	6.0	4.28	42.8
Mar	3	Mid	1.06	4.86	53.5	7.8	4.15	45.6
Apr	1	Mid	1.06	4.84	48.4	7.5	4.09	40.9
Apr	2	Mi/Lt	1.03	4.68	46.8	8.2	3.86	38.6
Apr	3	Late	0.96	4.18	41.8	18.7	2.31	23.1
May	1	Late	0.87	3.66	36.6	30.3	0.62	6.2
May	2	Late	0.78	3.19	25.6	31.8	0.00	0.0
Total					**544.1**	**119.2**		**431.2**

Appendix Table 6 CROPWAT 8 output for tomato water requirement

Month	Decade	Stage	Kc Coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	IR mm/day	IR mm/dec
Dec	3	Ini	0.50	1.90	13.3	0.3	1.85	12.9
Jan	1	Ini	0.50	1.94	19.4	1.0	1.84	18.4
Jan	2	Ini	0.50	1.97	19.7	0.8	1.89	18.9
Jan	3	In/De	0.58	2.36	25.9	0.7	2.29	25.2
Feb	1	Deve	0.75	3.17	31.7	0.2	3.14	31.4
Feb	2	Deve	0.94	4.11	41.1	0.0	4.11	41.1
Feb	3	De/Mi	1.10	4.90	39.2	1.6	4.70	37.6
Mar	1	Mid	1.17	5.28	52.8	4.2	4.86	48.6
Mar	2	Mid	1.17	5.36	53.6	6.0	4.76	47.6
Mar	3	Mi/Lt	1.16	5.29	58.2	7.8	4.58	50.3
Apr	1	Late	1.10	4.98	49.8	7.5	4.24	42.4
Apr	2	Late	0.99	4.49	44.9	8.2	3.67	36.7
Apr	3	Late	0.89	3.89	38.9	18.7	2.02	20.2
May	1	Late	0.79	3.36	26.9	24.3	0.33	2.6
Total					**515.4**	**81.5**		**433.9**

Appendix Table 7. Canal discharges at different points and conveyance efficiency of Ashar scheme

Field code	Q ($m^3 s^{-1}$) Maincanal		Q ($m^3 s^{-1}$) 2^0 canal		Q ($m^3 s^{-1}$) 3^0 canal		Q (m^3 s-1) field canal	Ec (%)
	Initial	Final	Initial	Final	Initial	Final		
H	0.085766	0.083567	0.055567	0.044548	0.023568	0.018468	0.018468	61.21
M	0.086767	0.079869	0.051458	0.039589	0.019549	0.016472	0.016472	59.95
T	0.084975	0.078277	0.049858	0.038987	0.018967	0.016680	0.016680	62.97
Average								61.38

Note: - H are code of fields selected from head water users, M are code of fields selected from middle scheme water users, and T are code of fields selected from tail end water users, Q is discharge of water, 2^0 secondary canals, 3^0 tertiary canals and Ec is conveyance efficiency.

Appendix Table 8. Measured water depths applied to field, field application efficiency and storage efficiency of Ashar irrigation scheme.

FC	H					M					T				
stage	Wf(mm)	Zr(mm)	Wn(mm)	Ea(%)	Er(%)	Wf(mm	Zr(mm)	Wn(mm)	Ea(%)	Er(%)	Wf(mm)	Zr(mm)	Wn(mm)	Ea(%	Er(%)
Initial	71.04	36.18	68.03	50.93	53.18	62.18	34.72	63.52	55.84	54.66	68.53	34.39	66.08	50.18	52.04
Dev	60.52	38.42	73.50	63.48	52.27	73.81	36.28	71.00	49.15	51.09	77.61	39.95	74.57	51.48	53.57
Middle	56.12	41.31	77.18	73.61	53.52	75.69	39.93	79.50	52.75	50.23	75.61	41.82	78.64	55.31	53.18
Ave				62.67	52.99				52.58	51.99				52.32	52.93

Note: -Wf = Water applied to the field (mm), Zr = Depth of water applied to the root zone as storage (mm), Wn = Water needed in the root zone prior to irrigation (mm), Ea = Application efficiency and Er = Storage efficiency

Appendix Table 9 Distribution uniformity of the three-field location

Stages	Field location in the scheme					
	H		M		T	
	0 - 40	40 - 80	0 - 40	40 - 80	0 - 40	40 – 80
Initial	96.3	93.5	90.4	72.2	88.7	89.5
Development	89.4	77.8	84.5	95.3	93.6	93.4
Mid-season	89.2	85.6	91.0	94.1	92.4	91.2
DU average	**88.63**		**87.92**		**91.47**	

Appendix Table 10 Summary of field efficiencies and losses for three selected fields

		Efficencies			Losses
Test plot location	Crop stage	Ea (%)	Er (%)	DU (%)	DPR (%)
H	Initial	50.93	53.18	94.9	49.07
	Dev`t	63.48	52.27	83.6	36.52
	Middle	73.61	53.52	87.4	26.39
	Average	62.67	52.99	88.6	37.33
M	Initial	55.84	54.66	81.3	44.16
	Dev`t	49.15	51.09	89.9	50.85
	Middle	52.75	50.23	92.6	47.25
	Average	52.58	51.99	87.6	47.42
T	Initial	50.18	52.04	89.1	49.82
	Dev`t	51.48	53.57	93.5	48.52
	Middle	55.31	53.18	91.8	44.69
	Average	52.32	52.93	91.5	47.68

Appendix Table 11. Average irrigation efficiencies at Asher irrigation schemes

Internal indicators	Scheme efficiencies (%)			
	Field Code			
	H	M	T	Ave

Conveyance Efficiency	61.21	59.25	62.97	61.38
Application Efficiency	62.67	52.58	52.32	55.86
Deep percolation Ratio	37.33	47.42	47.68	44.14
Storage Efficiency	52.99	51.99	52.93	52.64
Distribution Uniformity	88.63	87.92	91.47	89.34
Overall Scheme Efficiency	38.36	31.15	32.95	34.15

Appendix Table 12. Applied water depth profile for three growth stages

FC	Stage	Water head (cm)	Canal width (cm)	Velocity (m/s^{-1}	Q (m^3/s^{-1})	Et (sec)	Aea (ha)	Vt (m^3)	Wf (mm)
H	Initial	18	15	0.685	0.0185	9600	0.25	177.6	71.04
	Dev’t	19	15	0.585	0.0167	9060	0.25	151.30	60.52
	Middle	21	15	0.502	0.0158	8880	0.25	140.30	56.12
M	Initial	21	15	0.521	0.0164	9480	0.25	155.47	62.18
	Dev’t	18	15	0.674	0.0182	10140	0.25	184.54	73.81
	Middle	16	15	0.792	0.0190	9960	0.25	189.24	75.69
T	Initial	19	15	0.586	0.0167	10260	0.25	171.34	68.53
	Dev’t	18	15	0.637	0.0172	11280	0.25	194.02	77.61
	Middle	21	15	0.568	0.0179	10560	0.25	189.02	75.61

Note: - Et is elapsed time and Vt is total volume