

Adama Science and Technology University
School of Civil Engineering and Architecture

Water Resources and Irrigation Engineering Program

Performance Evaluation of Katar Irrigation Scheme

By

- 1. Mulugeta Kebede**
- 2. Mesfin Benti**

September, 2017

Table of Contents

| | |
|--|----|
| ABSTRACT..... | 4 |
| 1. INTRODUCTION..... | 5 |
| 1.1. Background | 5 |
| 1.2. Statement of the Problem | 7 |
| 1.3. Objectives of the Study | 8 |
| 2. LITERATURE REVIEW | 9 |
| 2.1. Overview of Ethiopian irrigation | 9 |
| 2.2. Existing Irrigation Schemes with Database..... | 12 |
| 2.3. Small and medium scale irrigation..... | 12 |
| 2.3.1. Size of command area based classification..... | 12 |
| 2.3.2. Management based | 12 |
| 2.4. Challenges of irrigation development..... | 13 |
| 2.5. Environmental impacts of irrigation schemes | 15 |
| 2.6. Performance of irrigation schemes..... | 17 |
| 2.6.1. Internal performance indicators | 18 |
| 2.6.2. External performance indicators | 21 |
| 3. MATERIALS AND METHODS..... | 24 |
| 3.1. Description of the study area | 24 |
| 3.1.1. General description of the Ketar basin..... | 24 |
| 3.1.2. Ketar River..... | 25 |
| 3.1.3. Ketar irrigation..... | 25 |
| 3.2. Performance evaluation methodology | 26 |
| 3.2.1. Data collection | 26 |
| 3.2.2. Soil Analysis | 27 |
| 3.2.3. Internal process indicators | 28 |
| 4. RESULTS AND DISCUSSION | 30 |
| 4.1. Soil Physical Properties | 30 |
| 4.2. Irrigation Water Distribution System..... | 31 |
| 4.3. Internal Process Indicators..... | 32 |
| 4.3.1. Conveyance efficiency..... | 32 |
| 4.3.2. Application efficiency..... | 33 |

| | | |
|--------|---------------------------------|----|
| 4.3.3. | Deep percolation ratio | 36 |
| 4.3.4. | Storage efficiency | 36 |
| 4.3.5. | Overall Scheme Efficiency | 37 |
| 5. | SUMMARY AND CONCLUSIONS | 38 |
| 6. | REFERENCES | 40 |
| 7. | APPENDICES | 42 |

ABSTRACT

This study was conducted to evaluate the performance of Ketar irrigation schemes at Tiyo Werda, Oromia Regional State, using internal performance indicators. The irrigation scheme included in the study has three Command areas Ketar I area of 120 ha and 273 beneficiaries, Ketar II with area 226 ha and beneficiaries, 225 and Ketar III with 154 ha command area and 359 beneficiaries. To achieve the objective primary and secondary data were collected. Primary data collection includes, canal discharges, soil moisture before and after irrigation and depth of water applied. The secondary data includes crop types, total yields, farm gate prices of irrigated crops, area irrigated per crop per season, incomes generated by the irrigation associations,. The irrigation scheme was compared using minimum sets of comparative performance indicators. The internal process indicators which include conveyance, application, storage, , runoff ratio, deep percolation ratio and overall irrigation efficiency were used to check the performance of the irrigation scheme at the three sites. From the analyses of the internal performance indicators, the conveyance efficiencies were found to be 61.24 , 68.32%, and, 69.84 % at Ketar I Ketar II, and Ketar III , respectively. The runoff ratio for the three sites of the scheme was nil as the furrows are closed end type. Deep percolation ratios in the same order of the sites scheme were found to 38.76 %, 31.58 % and 39.54. The result of storage efficiency of selected fields from the three command area of ketar irrigation scheme were found to vary from 41.83% to 51.630%, with an average storage efficiency of 45.68% in Ketar I , 43.79 to 54.90 with average 49.16 % in Ketar II and 33.98 to 44.83 % with average 41 % in Ketar III. In general, the overall efficiencies of the irrigation at command areas of Ketar I, Ketar II and Ketar III of the irrigation scheme were found to be 40.17 %, 38.17 % and 47.38 %, respectively.

1. INTRODUCTION

1.1. Background

The world's population is increasing resulting in increasing demand of food and fiber. On the other hand, per capita land and water resources are decreasing at alarming rate. Water is valuable natural resource, which is used for agriculture, recreation and industrial purpose. Due to industrialization and population growth the demand and utilization of water is increased which increased pressure on the water resources. The major portion of the water resource is used in agriculture sector for irrigation purpose to enhance the crop production. The growing demand for household and development purpose, forced the share of the irrigation water to be diverted for industries, recreation and drinking purpose. Therefore it is need of the time to utilize the available water resources optimally and judiciously with multipurpose use (P.I.Igle., *et al*, 2015).

Agriculture employees 85 % of the population, which currently is approaching nearly 80 million, depends on agriculture for a living and live in rural areas (Awulachew 2006; UNDP 2006). As noted by the World Bank (2006) report: "The very structure of the Ethiopian economy with its heavy reliance on rain-fed subsistence agriculture makes it particularly vulnerable to hydrological variability. Its current extremely low levels of hydraulic infrastructure and limited water resources management capacity undermine attempts to manage variability. These circumstances leave Ethiopia's economic performance virtually hostage to its hydrology." UNDP (2006) notes that failed rains will send shock waves beyond the household to the entire economy. It is estimated that in Ethiopia, one drought event in 12 years lowers GDP by 7 to 10% and increases poverty by 12 to 14%. The World Bank estimates that the inability of Ethiopia to reduce the impact of rainfall variability results in a one-third reduction in Ethiopia's potential for economic growth (UNDP 2006). This situation makes it imperative for development efforts in Ethiopia to 'de-link' the performance of the economy from rainfall variations.

Food security in developing nations is aggravated by the rapid population growth and the consequent demand for food. Exacerbating this increased food demand, there has been a significant rise in prices of food products in the world market. Consequently, to better meet the demand for food and reduce the impact of inflated food prices, substantial investments in modifying existing farming systems or establishing new ones will be necessary (FAO, 1997).

There are mixed perceptions about the contribution of irrigation in general and small scale irrigation (SSI) interventions in particular for poverty reduction and food security improvement. In Ethiopia, although irrigation has been long practiced at different farm levels, there is no efficient and well-managed irrigation water practice (Dessalegn, 1999). The reason could be little efforts made to investigate the irrigated land management and water use in the country. Even some research results have indicated that sometimes no difference is observed between rainfed and SSI user smallholders in their food security status (Peden et al., 2002). The world major grain exporters such as USA, Canada, France, Australia and Argentina produce grain on very productive rainfed agricultural lands, while major grain importers depend on the irrigation to produce grain (De Fraiture et al., 2009). According to Shah et al. (2002), SSI development should result in substantial improvement in household food security and poverty reduction through low cost of maintenance and better institutional support for its sustainability and national economic benefit. A review of several empirical studies by Hussain and Hanjira (2004) indicated a strong linkage between irrigation development and poverty reduction through improving level and security of productivity, livelihood diversification as well as creating employment and income opportunities. Out of 200 sampled irrigator and non-irrigator households in a particular area of Oromia region, only 45 % of them were food secure and more than 70 % of food secured sampled households were irrigators (Tesfaye et al., 2008).

It has been clearly and loudly stated that if Ethiopia is to feed its ever increasing population, lessen risk of catastrophes caused by drought, continuous and extensive effort need to be made towards developing irrigated agriculture and intensifying agricultural production. That is why, in addition to existing schemes, the government prepared a 15 years water sector plan to develop 471,862 ha of irrigation farm out of which 225,763 ha is small scale and 246,099ha is large scale (MoWR , 2002).

Ethiopia has an estimated irrigation potential of 3.7 million hectares (ha) of land (Awulachew *et al.*, 2007). 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, 2006). 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.

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

Performance assessment is used to identify the present status of the scheme with respect to the selected indicators and will help to identify 'why the scheme is performing so' which in turn imply means of improvement. Of course performance evaluation needs relevant and reliable data which is rarely measured in Ethiopia. To improve the productivity of irrigated farms and effective utilization of water and land resources, performance assessment of irrigation schemes in the country is very crucial.

1.2. Statement of the Problem

For Ethiopia ensuring food security stands out as the most pressing agenda now and for the coming decades. It has also been indicated that both chronic and transitory problems of food insecurity are severe in Ethiopia.

Even though numbers of modern small scale irrigation schemes were developed in moisture stress districts of Ormia region, the irrigation schemes have not achieved their primary objective successfully. Most irrigation schemes are poorly operated and managed. So one of the most

important aspects of irrigation schemes development is not only the construction but also to know how irrigation scheme systems operate and how communities manage and participate in irrigation schemes management.

In order to understand the cause for underperforming, examining the physical irrigation system, water use, irrigation institutions and critical environmental concern are predestined.. Irrigation water management information on farmer fields is not available. Thus, this study has been focusing on evaluating the irrigation scheme water management condition of katar irrigation schemes

1.3. Objectives of the Study

Having the above mentioned problems in consideration this study was conducted with objective to investigate the performance of katar irrigation scheme.

Specific objectives

- To assess the conveyance efficiency of the irrigation schemes
- To determine the application efficiency, storage efficiency, deep percolation ratio and overall efficiency of the irrigation schemes.

2. LITERATURE REVIEW

2.1. Overview of Ethiopian irrigation

Ethiopia has a total area of 1.12 million square kilometers (CSA 2007). The country is heavily dependent on rainfed agriculture with about 12 million ha currently under cultivation. This area can be substantially increased if the necessary infrastructure is put in place. Irrigation is one means by which agricultural production can be increased to meet the growing food demands of the fast growing population of the country. Increasing food demand can be met in one or a combination of three ways: (i) increasing agricultural yield, (ii) increasing the area of arable land, and (iii) increasing cropping intensity by growing two or three crops per year using irrigation. Expansion of the area under cultivation is a limited option. However, increasing yields under both rainfed and irrigated agricultural systems and cropping intensity in irrigated areas through various methods and technologies are the most viable options for achieving food security in the shortest time span. The problems of crop failures, due to dry spells and droughts are common events in the rural settings of Ethiopia (MoA,2011).

World Bank (2006) recommends major investments in water resources infrastructure as one possible mechanism to ‘de-link’ Ethiopia’s economic performance from rainfall, and thus enable sustained growth. Ethiopia has ample water resources that could be developed, for example, by developing storage facilities. Even though it has uneven spatial and temporal distribution, resulting in droughts in some parts of the country, it is estimated that Ethiopia has more than 122 billion cubic meters (BCM) of surface runoff from 12 river basins, not considering groundwater (Government of the Republic of Ethiopia 1999). This amounts to a per capita water availability of about 1,644 cubic meters (m³), which makes Ethiopia a water-abundant country (UNDP 2006). The United States stores 6,000 m³ of water per person, Australia 5,000 m³, while Ethiopia stores only 43 m³ per person. While water use in Ethiopia is estimated to be about 30 liters per person per day (l/ person/day), it is more than 150 l/per person/per day in the UK and Brazil and stands at more than 550 l/per person/per day in the USA (UNDP 2006). This means that in Ethiopia there is potential for developing water facilities, for instance, storage, that could be used for multiple purposes, irrigation. Estimates of irrigable land in Ethiopia vary between 1.5

and 4.3 million hectares (Mha), depending on the assessment criteria used, with about 3.5 Mha generally agreed as the accurate estimate (Werfring 2004; Awulachew et al. 2005; Government of the Republic of Ethiopia 2001a; World Bank 2006; Makombe et al. 2007). Makombe et al. (2007) highlight the Ethiopian paradox, where in spite of the combination of having potentially irrigable land and an abundance of surface runoff that has earned the country the nickname ‘The water tower of Africa’, 52% of the population is considered food insecure (Kassahun 2007) and the country annually received about 750,000 metric tonnes (Mt) of food aid to feed about 5.5 million people (or 10% of its population) between 1998 and 2004 (Government of the Republic of Ethiopia 1998-2004). The Government of Ethiopia believes that irrigation development, as a component of an agriculture-led development program, can contribute to solving this paradox by playing a major role in the country’s economic development program (Government of the Republic of Ethiopia 2003). Given the high dependence of Ethiopia’s economy on agriculture, and the availability of both water resources and irrigable land, it is surprising that less than 5% of the country’s irrigable land has been developed for irrigation (World Bank 2006; Makombe et al. 2007).

Agricultural production can be stabilized and increased by providing adequate supply of water through irrigation and retaining of rainwater to increase the soil moisture to be utilized by crop plants using different in- situ moisture conservation techniques to produce surplus that can bridge the gaps during drier years. Although traditional irrigation has been practiced in the highlands for centuries, particularly for producing subsistence food crops, it was only in the early 1950s that modern irrigation technologies were introduced to Ethiopia by a Dutch company in the Upper Awash Valley with the objective of producing industrial crops such as large-scale sugarcane plantations. It is expected that through an optimal development of water resources, in conjunction with development of land and human resources, a sustainable growth of food production can be achieved to fulfill the food requirements of the country as well as to adequately supply the required agricultural raw materials for the domestic industries and factories and generate increased amounts of export earnings.

Most of the irrigated land is supplied from surface water sources, while ground water use has just been started on pilot basis in East Amhara. Surface irrigation methods dominate throughout.

Sprinkler irrigation system is being practiced on about 10,000 ha area for sugarcane production in Fincha and Wonji State Farms. Similarly, it is being used in some localized areas of eastern Amhara and southern Tigray under smallholders' conditions and on some private farms in the Rift Valley. The technologies were adopted in large private- and government- owned schemes, primarily in the Awash River Basin. Most of the earlier schemes were pump-irrigation projects, but later gravity irrigation schemes were introduced. In all cases, the irrigation method was surface irrigation, predominantly furrow irrigation for cotton and wheat and basin irrigation for commercial fruits such as bananas. Some private farms had installed hydraulic rams on the banks of the Awash River to lift up water. In the mid-1970s, windmills and hand pumps were introduced to lift water from boreholes, mainly to supply water for drinking, domestic purposes and for gardening (MoA, 2011).

Despite, the efforts of the government made to expand irrigation, the country has not yet achieved sufficient of its aspirations in the sub-sector to overcome the problems of food insecurity or curb the situation of abject rural poverty. The problems associated with agricultural production in Ethiopia are deep-rooted and complex. Notwithstanding this fact though the following could be cited as the major constraints impeding development in the irrigation sub-sector: (i) predominantly primitive nature of the overall existing production system, (ii) shortage of adequate agricultural inputs and limited improved irrigation technologies, (iii) limited trained human power, (iv) inadequate extension services, and (v) heavy capital requirement. Irrigation development, particularly in the peasant sub-sector has significant importance to raise production and productivity to achieve food self-sufficiency and ensure food security at national level in general and household level in particular. The irrigated agriculture can also play a vital role in supplying sufficient amounts of raw materials at the required quality standards for domestic agro-industries and also increase export earnings. Therefore, considering the importance of the irrigation sub- sector in the overall growth of the agriculture sector, the Government of Ethiopia is giving special emphasis to enhance irrigated-agriculture. Efforts are being made to involve farmers vigorously in various aspects of management of small-scale irrigation systems, starting from the process of planning through to the implementation and management facets of project development, particularly in water distribution, operation and maintenance to ensure sustainability of the performance of the scheme put in place (MoA, 2011).

2.2.Existing Irrigation Schemes with Database

Based on the Ministry of Water Resources (MoWR, 2002) classification, irrigation projects in Ethiopia are identified as large-scale irrigation if the size of command area is greater than 3,000 hectares, medium-scale if it falls in the range of 200 to 3,000 hectares and small-scale if it is covering less than 200 hectares (see also Werfring (2004); Awulachew et al. (2005)).

According to the database developed in (MoWR, 2002) study, in 2002, data on 791 schemes has been collected from different regional states of Ethiopia. According to the database, the total estimated area of irrigated agriculture in the country is 107,265.65 hectares out of which 20,038.39 hectares is from small-scale, 30,291.26 hectares is from medium-scale and 56,936 hectares is from large scale.

2.3.Small and medium scale irrigation

2.3.1. Size of command area based classification

Irrigation systems in Ethiopia are classified based on size of the command area as follows:

1. Small-scale irrigation systems (<200 hectares (ha))
2. Medium-scale irrigation systems (200-3,000 ha)
3. Large-scale irrigation systems (>3,000 ha)

2.3.2. Management based

1. Traditional schemes: These are small-scale irrigation systems which usually use diversion weirs made from local material and need annual reconstruction. The canals are usually earthen and the schemes are managed by the community. Many were constructed by local communities and have been functional for very long periods of time, while some were recently constructed with the aid of nongovernmental organizations (NGOs) and the government.

2. Modern schemes: These are small-scale irrigation systems with more permanent diversion weirs made from concrete and, therefore, do not require annual reconstruction. The primary and

sometimes secondary canals are made of concrete. They are community-managed and have recently been constructed by the government.

3. Public: These are large-scale operations constructed and managed by the government.

Sometimes these schemes support out-growers (smallholder farmers who have farms in the vicinity of the large-scale schemes).

4. Private: These are privately owned systems that are usually highly intensive operations.

Given our interest in small-scale irrigation, which is distinguished from large-scale irrigation by the farm-level scale of operation, we prefer to identify the small-scale irrigation systems using the second classification system and we studied the first and second categories of this classification. Werfring (2004) describes the typology of Smallholder Scale Irrigation (SSI) in Ethiopia in detail. Table 2 presents the estimated areas developed under each management system. According to this classification, it is estimated that 156,000 ha of irrigation are developed. The figures of the proposed irrigation development presented in Table 1 are based on a plan spanning the period 2002-2016. A more recent planning document, the 'Plan for Accelerated and Sustained Development to End Poverty (PASDEP),' which spans the years 2005 to 2010 was aimed at developing about 430,061 ha within this planning period – 2005 to 2010 (Government of the Republic of Ethiopia 2006). This planning document was focused on strongly developing and

2.4.Challenges of irrigation development

According to (IWMI, 2010), Ethiopia faces four key technical, socio-economic, institutional, and environmental challenges that must be overcome in order to meet the irrigation development plan.

Behind-schedule scheme delivery. There is often a significant gap between plans for irrigation projects (number of projects, number of hectares to be irrigated) and the actual construction or delivery of these projects. For example, the 2010 irrigation target from the PASDEP I plan was 820,000 hectares of irrigated land (75 percent by SSI or RWH and the remaining with M&LSI). But by mid-2010, only 640,000 hectares were equipped, which was 180,000 ha short of the target.

Low-performance of schemes. Many schemes currently operate significantly under their design capacity. The research team estimates that scheme performance is on average 30 percent below design, implying a loss of about 230 thousand hectares of irrigated land, leading to only 410,000ha performing to the expectations^{xiv}.

The second hurdle to irrigation development is the underperformance of existing irrigation schemes. Many irrigation projects are operating significantly under their design capacity, with the schemes analyzed below operating at just 64 percent of their design capacity (640,000 ha equipped capacity versus 410,000 ha actually operational), and small-scale schemes accounting for 90 percent of the gap. Under-performance is an issue for all scheme types (small, medium, large) in all three zones.

There are multiples reasons for this low performance:

■ **Operations/maintenance.** Extensive research shows that non-/under-performance is caused primarily by inadequate operations and maintenance (O&M) of projects, e.g., sedimentation impact, inadequate structural design^{xvii}; smallholders' limited skills in the operation and maintenance of small-scale projects; and poor contract and performance management for medium- and large-scale intervention schemes, among other issues. The authors for this report observed many of these constraints during a field visit to the Oromia region. In addition, scheme performance often deteriorates over time due to wear and tear of irrigation structures and depletion of soil quality, making operations and maintenance especially important.

■ **Human capacity.** Human capacity is limited across multiple government and private sector actors. This includes a shortage of skilled workers (e.g., engineers, designers) to build and maintain projects and a lack of basic irrigation skills among farmers and development agents to operate and maintain small-scale projects.

■ **Research/management capabilities.** There is no coordinated research program on agricultural water management, no applied research on national irrigation systems, no link between researchers and farmers, and no manuals on irrigation for local crops. There is also poor management of project contracts and

performance – including non-transparent bidding and selection processes, lack of contract management skills, lack of checks and balances – all of which can increase project costs, delivery time, and risk.

To address these challenges, the authors recommend several efforts, including prioritizing applied research on irrigated agriculture, enhancing the training of farmers and development agents on agricultural water management through the extension system, and improving contract management for medium and large irrigation schemes.

■ **Constraints on scale-up of irrigation projects.** The GOE’s aspiration to nearly triple the number of irrigated hectares over the next five years will only be met by overcoming a series of scale-up constraints such as inadequate funding, human capacity and labor constraints, and limited private sector involvement.

■ **Protecting irrigation development sustainability.** Sustainability is threatened by unregulated surface and groundwater development, lack of watershed and environmental management, and the need for smallholder farmer buy-in and investment. For example, land degradation caused by soil erosion (about 1.9 billion tons of topsoil are lost annually in Ethiopia,^{xv} negatively affects agricultural productivity, and salinity is already an issue in some large-scale irrigation settings.

The following sections provide an in-depth exploration of these four challenges in terms of institutional, human and technical capacity, capability, policy context, and funding. The constraints are explored at each decision-making level (federal, regional, *woreda*, farmers).

2.5.Environmental impacts of irrigation schemes

In several studies a number of different environmental impacts have been identified which are directly caused by irrigation projects. Sectoral guidelines to conduct environmental impact assessments of irrigation projects (e.g. FAO, MoWR) use checklists which include the pertinent environmental impacts. These potential impacts are grouped into impact categories such as economic, socio-economic, natural resource and ecological impacts.

Irrigation is useful only when it is properly managed and controlled. Faulty and careless irrigation water management practices do harm to crops and damage the land and ultimately reduce crop yields. Besides, excess watering is a waste of the valuable and scarce resource- the

water. Traditionally, including the Ethiopian experience when water is excessively available, farmers are usually tempted to over- irrigate their lands without being conscious of the harmful effects of overwatering on their fields (MoA, 2011). Therefore, the following are some harmful effects of faulty and excess irrigation practices:

- **Poor soil aeration:** Excess irrigation fills the pores with water expelling soil air completely and this leads to deficiency of oxygen, which affects the root respiration and normal growth of crop plants.
- **Increase nutrient toxicity level to crops:** In excess water application nutrients such as manganese and iron become more soluble and their increased availability may be toxic to plants.
- **Creates physiological imbalance in plants:** Physiological activities of plants will seriously be affected, due to lack of adequate oxygen in poorly aerated soil.
- **Restricts the root system:** Lack of adequate oxygen, restricts the root development. Roots do not grow well in wet soil conditions and usually remain shallow and affects the nutrient uptake of plants that ultimately affect crop growth and resulted in reduced crop yields.
- **Increases soil erosion and lead to degradation of soil fertility status:** Heavy irrigation in areas of sloping and undulating lands may cause erosion of surface soil. The stream size and amount of irrigation water applied should be decided based on the water intake rate, hydraulic conductivity, textural class and water retentive capacity of the soil, land slope and soil water depletion status in order to minimize the likely erosion hazard and leaching of nutrients beyond the active root zone.
- **Rise of water table:** Faulty and over- irrigation in a farm, if continued for a long period leads to rise of water table. The rise of water table restricts the root development and limits the feeding zones of crops. Growing of fruit trees and deep- rooted crops in areas, where the water table rises high up and gets near the soil surface, is not suitable. Instead, shallow rooted- crops are recommended to be cultivated in such conditions.
- **Creates water logging:** When irrigation is done in a large stream size and if not turned off in the proper time, excess water accumulates in the lower part of the field and causes water logging. The water logging further destroys the crumb structure and soil aggregates and encourages the development of platy structure, which is not suitable for crop production. Therefore, controlling of the stream size and constructing of drainage systems is highly

essential to drain out excess water and create favorable conditions for normal growth and development of crop plants. **Affects activities of micro- organisms:** Useful aerobic bacteria such as ammonifying, nitrifying and nitrogen fixing bacteria cannot function well under deficiency of oxygen. As a result, decomposition of organic matter, atmospheric nitrogen fixation and availability of nutrients to plants are hampered. On the other hand, anaerobic bacteria are activated causing loss of nitrogen in the form of gas, evolution of harmful gases and encourages incidence of plant diseases.

- **Increases incidence of malaria and other water borne diseases:** Waterlogged areas are ideal sites for breeding of mosquitoes and enhance the outbreak of malaria and water borne diseases. Therefore, basic knowledge and skills are required for efficient water management practices.

2.6. Performance of irrigation schemes

Sustainable Irrigation has crop water supply, irrigation agronomy and scheme administration, which in turn the scheme administration can be classified as facility management, operation, water management and organizational management. An irrigation which fails to address all the above properly will endanger the scheme and negatively impacts the environment. Specially, if the water is not managed properly the impact will be irreversible, salinity can develop, water logging affects the crops, erosion can impact the plots, and conflicts can arise between upstream and downstream and also among beneficiaries (CBID, 2014).

In response to the insufficient performance of existing irrigation system, focus was made on the performance evaluation of the schemes. This led to the establishment of performance criteria such as productivity, adequacy, equity, etc. However, in conducting performance of irrigation, more than one viewpoint exists. In addition, few of these criteria reflect the view of the farmers (Gowing *et al.*, 1996). It is therefore essential that evaluation of the performance of surface irrigation systems be continued with a view to improve the performance of the systems and also to incorporate the view of the stake holders, i.e., the farmers in particular.

Different indices have been developed that are used for evaluating the performances of individual irrigation systems and for comparing the performances of different irrigation systems

as well as farms. The type and number of indices (indicators) used for a particular situation depend on the level of details required for quantification, and on the number of disciplines selected for assessment. These may include, Agricultural, water use, economics, environment, management, physical etc. which are regarded as external indicators (Bos, 1997).

The common efficiency terms used for on-farm irrigation system evaluation (internal process indicators) include application efficiency, uniformity, storage efficiency and adequacy, and recently complementary terms such as runoff ratio, deep percolation ratio, are being applied (Jureims *et al.*, 2001). The principal terms and their uses are described as follows.

2.6.1. Internal performance indicators

These indicators examine the technical or field performance of a project by measuring how close an irrigation event is to an ideal one. An ideal or reference irrigation is one that can apply the right amount of water over the entire region of interest (i.e. depth of root zone) uniformly and without losses. Analysis of the field data allows quantitative definition of the irrigation system performance. The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field (Feyen and Dawit, 1999).

2.6.1.1. Conveyance efficiency

Significant volume of water is lost by the net works 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).

2.6.1.2. 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 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 E_a (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%).

2.6.1.3. Deep percolation ratio

A component of the irrigation applied to a field percolates into the soil below the root zone. Part of the water is intentionally added to the irrigation water to maintain the salt balance of the soil through leaching additional salt brought by the irrigation water itself or through capillary process from saline 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).

2.6.1.4. Storage efficiency

Storage efficiency is an index used to measure irrigation adequacy. It is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root zone. The value of E_r 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 Wallender, 1998).

2.6.1.5. Overall scheme efficiency

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

2.6.2. External performance indicators

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 are grouped as follow:

2.6.2.1. Irrigated agriculture performance indicators

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

$$\text{output per harvested area} \left(\frac{\text{tons}}{\text{ha}} \right) = \frac{\text{Production(tons)}}{\text{irrigated cropped area(ha)}} \quad 1$$

$$\text{output per harvested area} \left(\frac{\text{US\$}}{\text{ha}} \right) = \frac{\text{local value of production (US\$)}}{\text{Irrigated cropped area(ha)}} \quad 2$$

$$\text{output per command area} \left(\frac{\text{US\$}}{\text{ha}} \right) = \frac{\text{local value of production(US\$)}}{\text{Command area(ha)}} \quad 3$$

$$\text{out put per water supplied} \left(\frac{\text{US\$}}{\text{ha}} \right) = \frac{\text{local value of production (US \$)}}{\text{Diverted irrigation supplied(m3)}} \quad 4$$

2.6.2.2. Water use performance indicators

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

$$E_c = \frac{\text{water flowing out of the system}}{\text{water flowing in to the system}} \quad 5$$

$$AWRS = \frac{\text{Total volume of water supplied}}{\text{Total volume of water crop water demand}} \quad 6$$

$$ARIS = \frac{\text{Total volume of irrigation water diverted}}{\text{Total volume of irrigated water demanded}} \quad 7$$

$$WDR = \frac{\text{Volume of water actually diverted}}{\text{inteded volume of water to be diverted}} \quad 8$$

2.6.2.3. Physical performance indicators

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

2.6.2.4. Economic performance indicators

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

3. MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. General description of the Ketar basin

Physiography

The 3220 km² Ketar watershed is part of the Ziway–Shala basin, an internal drainage basin located in the central part of the Main Ethiopian Rift Valley. The Ketar River and its tributaries drain the highland area to the south and east of Lake Ziway. This lake is the most northerly of the Main Ethiopian Rift Valley lakes, and is fed principally by rivers draining the southeastern and northwestern plateaux and escarpments. Lake Ziway overflows to Lake Abiyata to the south. Topographically, the Ketar catchment shows a well pronounced variation with the altitude ranging from around 1700 m near Lake Ziway to about 4000 m on the high volcanic ridges along the eastern watershed. There is an intermediate plateau between 2000 and 3000 m followed by a series of steep rocky NNE–SSW running parallel faults leading from the plateau to the rift floor.

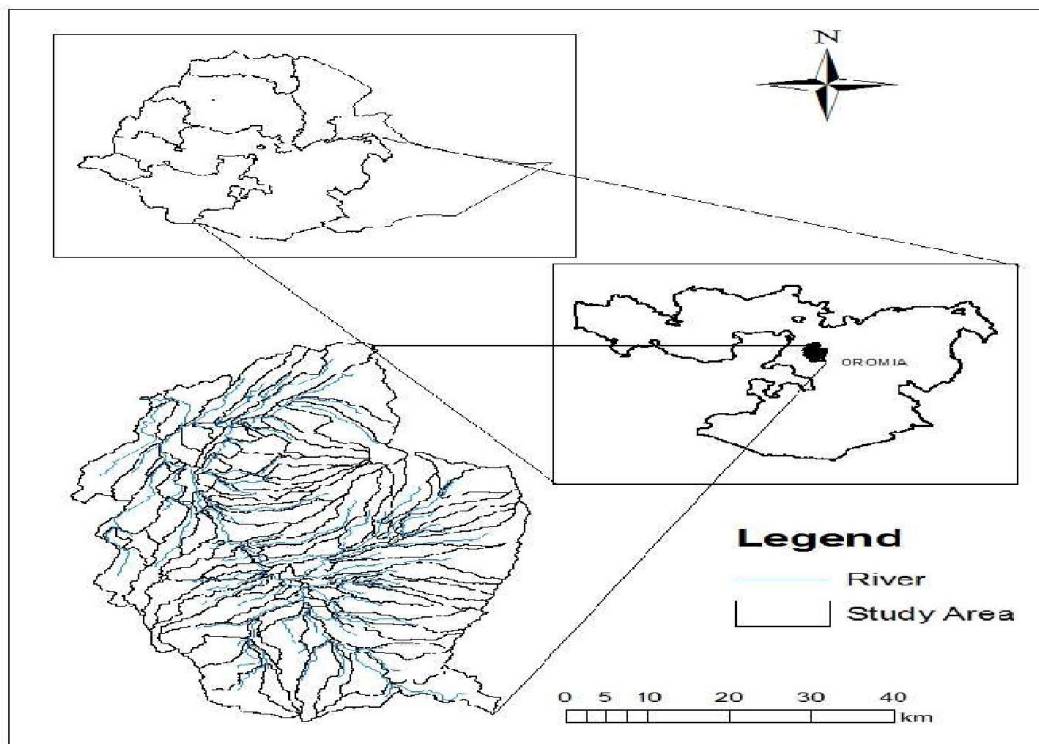


Figure 1: Location of the Study Area (Ketar Watershed) Damtew, 2016)

Climate

The Ketar catchment is characterised by a semiarid to subhumid climate with mean annual precipitation and mean annual temperature varying from 700 mm and 20 8C on the rift floor, to 1200 mm and 15 8C on the humid plateau and escarpment, respectively. The region is characterized by three main seasons. The long rainy season in the summer (June – September; summer monsoon rainfall, locally known as ‘kiremt’) is primarily controlled by the seasonal migration of the Inter Tropical Convergence Zone (ITCZ) which lies to the north of Ethiopia at that time. The ‘kiremt’ rain represents 50–70% of the mean annual total (Degefu, 1987). The dry period extends between October and February (known as ‘baga’) when the ITCZ lies south of Ethiopia. The ‘small rain’ season ‘belg’ representing 20–30% of the annual amount occurs during March to May when the ITCZ moves from south to north over the country.

3.1.2. Ketar River

The total catchment area of the river near Abura is 3350 km². According to discharge data recorded at Abura (1980-2004), average annual discharge of the river is 389.04 Mm³ or 12.26 m³/s. Monthly discharge of the river at Abura station is summarized in table.

Table 1 Monthly discharge of ketar river (1980-2004) sour MoWR, 2001)

| Average River Discharge (m ³ /s) | | | | | | | | | | | | | Annual Volume Mm ³ |
|---|------|------|------|------|------|-------|-------|-------|-------|------|------|-------|-------------------------------|
| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year | |
| 1.91 | 2.62 | 3.28 | 6.24 | 5.35 | 6.59 | 17.17 | 50.30 | 32.90 | 14.47 | 3.85 | 2.40 | 12.26 | 389.08 |

3.1.3. Ketar irrigation

The Ketar irrigation scheme was established by Ethiopian government in 1987. It is located in Tiyo wereda District, East Shoa Administrative Zone, Oromia Region at a distance of 110 km from Addis Ababa and 35 km from Assella town, along the Ketar River which serves as a source

of water for the scheme. The scheme comprises an area of 463 ha and 1043 beneficiary households.

In katar command area in the year 2015 and 2016, onion, cabbage, potato, carrot crops were grown. Crops were irrigated with canal water. Crops like Teff, maize, bean were also grown in the command area during the rainy season. At present 463 ha area was irrigated during *dry* season.

3.2.Performance evaluation methodology

3.2.1. Data collection

3.2.1.1.Primary data collection

Frequent field observations were made to observe and investigate the method of water applications, and practices related to water management techniques made by the farmers. Measurements of water discharge at diversion points of each irrigation scheme were taken and also at the initial and final points of secondary, tertiary and field canals. To determine soil texture of each farmer's field, nine soil samples from three locations from each scheme at three different depths were collected. And also using core sampler undisturbed soil samples were collected from different depths and the bulk densities at different depths were determined.

Soil samples were also collected to determine the soil moisture content one day before and after irrigation by collecting about 108 soil samples from the two schemes with an interval of 20 cm to a depth of 60 cm. It is presumed that the effective root zone of the irrigated vegetable crop is not more than this depth. The maximum effective root zone of onion is 60 cm (Allen *et al.*, 1998).

The moisture content of the collected soil samples was determined using gravimetric method.

The gravimetric moisture content on volume base was calculated using the equation (1) (FAO, 1989) as:

$$W_{\theta} = \frac{W_w - W_d}{W_d} \times 100 \times B_d \quad (8)$$

Where W_{θ} is gravimetric soil moisture content volumetric bases, W_w is wet weight of the soil

(g), W_d is dry weight of the soil (g) and B_d bulk density of soil ($g\ cm^{-3}$).

To determine the amount of water applied by the farmers to their fields, the average head of water passed through the field canal and width of field canal were recorded. The float methods was used to determine the velocity of water in field canal and then the amount of water applied to the fields were calculated by using this data . Total amount of water applied to the field is equal to:

$$W_f = h \times w \times v \times t \quad (9)$$

where W_f is total amount of water applied to field (m^3), h is height (head) of water in canal (m), w is width of canal (m), v is velocity of water ($m\ minute^{-1}$) and t is duration of time (minute) farmers irrigate a particular field.

3.2.1.2.Secondary data collection

For each of the selected irrigation schemes, secondary data were collected from the Tiyo wereda district Agricultural and Rural Development Office and Water Resource Offices and irrigation offices at regional and zonal levels. The secondary data included total yields, farm gate prices of irrigated crops, area irrigated per crop per season.

3.2.2. Soil Analysis

Soil samples were collected for analysis of selected soil physical properties. The properties analyzed were particle size distribution, bulk density and soil moisture contents at field capacity and permanent wilting point. Particle size distribution was analyzed using the Bouyoucos Hydrometer method. Bulk density was determined using the core method and water contents at field capacity and permanent wilting point were determined using the pressure plate apparatus method.

3.2.3. Internal process indicators

The internal performance indicators for each scheme were computed based on field measured data. Accordingly, the conveyance efficiency of the scheme was computed by taking discharges measurement at different points. The measurements were taken at a point of diversion and at the initial and final points of secondary, tertiary and field canals. It was computed as the follows (Ramulu, 1998):

$$E_c = \frac{W_f}{W_s} \times 100 \quad (10)$$

The conveyance efficiency of the scheme was computed as:

$$E_c = E_m \times E_s \times E_t \times E_f \quad (11)$$

where E_c is 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 depth of water diverted from the source (m³) and W_f is depth of water applied to the field (m³).

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 (0-20, 20-40 and 40-60 cm) and the amount of water stored in the root zone determined by gravimetric method. Application efficiency was computed as follows (Ramulu, 1998):

$$E_a = \frac{Z_r}{D} \times 100 \quad (12)$$

where E_a is application efficiency (%), Z_r 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 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):

$$DPR = 100 - E_a - RR \quad (13)$$

where DPR is deep percolation ratio (%), E_a is application efficiency and RR is runoff ratio. The storage efficiency is an index used to measure irrigation adequacy. It is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root zone. Based on the moisture content at field capacity, permanent wilting point and bulk density of the soils of the selected irrigation fields and the root depth of the crop irrigated, the depth of irrigation water required by the onion crop was calculated at the 25% moisture depletion level i.e. MAD of 0.25 (Allen *et al.*, 1998). After determining the storage and the required depths, the storage efficiency was calculated using the following formula (Ramulu, 1998):

$$E_r = \frac{D_{sr}}{W_n} \times 100 \quad 14$$

where E_r is storage efficiency (%), D_{sr} is water stored in the root zone (mm), and W_n is water desired to be stored in the root zone (mm). Distribution uniformity was determined by recording advance time and recession time at three equal points of the selected furrows. The depth of water infiltrated during the opportunity time was derived from measurement of the infiltration rate of the soil, which was determined using double ring infiltrometer.

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

$$E_p = E_c \times E_a \quad 15$$

where E_p is overall scheme efficiency (%), E_c is conveyance efficiency (%) and E_a application efficiency (%).

4. RESULTS AND DISCUSSION

4.1. Soil Physical Properties

The soil textural class in the project area are clay, clay loam heavy clay and loam for the selected farms at three Command area of the irrigation scheme, indicating that the majority of the soils the irrigation schemes is loam and clay loam in texture (Table 1). The bulk density values ranged from 0.98 to 1.18 g cm⁻³ at Katar I and 1.15 to 1.21 g cm⁻³ at Katar II and 1.12 to 1.23 g cm⁻³ at Katar III scheme. The bulk density values of the soils of the at the three command areas of the irrigation schemes are 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.

Volumetric moisture content retained at field capacity varied from 26-31 and 27-31% , 28-31 at Katar I Katar II and Katar III irrigation schemes, respectively, whilst the volumetric moisture content at permanent wilting point varied from 11-15% for soils of three sites of the scheme. Furthermore, the total available water holding capacity of soils selected fields from the three schemes ranged from 140-190 mm m⁻¹. In general soil of the three sites of the scheme are medium as per available water holding rating of McIntyre (1974). The result depict that the relevant soil physical properties measured are not different to a great deal from each other with depth and across the different sampling points indicate that the soils of the study area is homogeneous. The basic infiltration rate of soil at katar irrigation scheme was 25.50 mm hr⁻¹ and the same parameter for Katar II and Katar III was 22.5 mm hr⁻¹. The infiltration rate of the scheme was between the range recommended for loam soil (20 -30 mm hr⁻¹) (Savva and Frenken, 2002). The details of selected soil physical properties of the three sites (Katar I Katar II and Katar II) irrigation schemes are shown in Table 1.

The soil PH of the schemes at three sites ranges between 6.5- 7.5 Except Katar I which slightly Alkaline, Katar II and Katar II sites are Nuetral. The result of EC shows normal range for all sites of the scheme. The CEC result shows that medium to high cation exchangeable. Since at high PH the CEC (Na,K,Ca,Mg) availabilities are high except for saline soil those PH >7.8 and the soil are not strongly saline but slightly saline.

The result of OC and OM reveals that the soil have high to very high organic carbon and organic matter content.

Table 4. 1. Selected soil physical characteristics of Katar I II and III irrigation schemes

| Field name | Sample No | Soil Nutrients content | | | | | Soil Texture | | | |
|------------|-----------|------------------------|-----------------|------|------|-------|--------------|-------|-------|------------|
| | | PH | EC(μ S.cm) | %OC | %OM | %CEC | %Clay | %Silt | %Sand | Soil Class |
| Katar I | 1 | 7.78 | 17.2 | 5.07 | 8.74 | 34.2 | 25 | 32.5 | 42.5 | Loam |
| | 2 | 7.75 | 15.37 | 4.84 | 8.34 | 32.4 | 32.5 | 30 | 37.5 | Clay-loam |
| | 3 | 7.72 | 30.7 | 5.07 | 8.74 | 37.8 | 37.5 | 32.5 | 30 | Clay-loam |
| | 4 | 7.68 | 23.4 | 4.06 | 6.99 | 18.2 | 40 | 35 | 25 | Clay-loam |
| Ketar II | 5 | 7.15 | 17.3 | 3.43 | 5.92 | 31.68 | 65 | 25 | 30 | Heavy Clay |
| | 6 | 7.2 | 41.9 | 3.20 | 5.51 | 24.8 | 62.5 | 22.5 | 25 | Heavy Clay |
| | 7 | 7.26 | 26.1 | 3.98 | 6.86 | 28.6 | 37.5 | 32.5 | 30 | Clay-loam |
| | 8 | 6.98 | 13.01 | 4.13 | 7.13 | 31.68 | 42.5 | 30 | 27.5 | clay |
| Katar III | 9 | 7.14 | 17.3 | 3.51 | 6.05 | 36.4 | 42.5 | 30 | 27.5 | clay |
| | 10 | 7.65 | 25.26 | 3.51 | 6.05 | 33.8 | 25 | 42.5 | 32.5 | Loam |
| | 11 | 7.15 | 11.98 | 3.51 | 6.05 | 36.6 | 17.5 | 32.5 | 50 | Loam |
| | 12 | 7.12 | 19.2 | 3.51 | 6.05 | 7.8 | 45 | 25 | 30 | Clay |

4.2.Irrigation Water Distribution System

In Ketar irrigation scheme, water user association was grouped in to four groups namely, Ketar Fuafuate, Ketar Genet, Ab/Alko and Burqaa Soloboo. Irrigation management was carried out in rotation among the four groups in which the farmers are free to irrigate till they have received enough water. There was irregular irrigation interval in the scheme which varied from 5 to 7 days depending on their rounds. Regarding scheduling, all the four groups get water turn by turn and the method of water distribution was a rotational type. The availability of water for upstream and downstream farmers is not the same i.e. there is shortage water in the downstream. The irrigation interval in the initial period of the crops commonly grown in the area is about 4-5 days; which increases 6 to 7 days at the end of the growing season

4.3. Internal Process Indicators

4.3.1. 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. 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 command areas of ; Ketar I Ketar II, and Ketar III were found to be 61.24 , 68.32%, and, 69.84 % respectively. The details of conveyance efficiencies for selected fields of the three command areas of ketar the irrigation schemes are shown in Tables 4.2 4.3 and 4.4 and the average conveyance efficiencies presented in Table 4. 2.

Table 4.2. Canal discharges at different points and conveyance efficiency of Ketar I command area of ketar irrigation scheme

| Field code | Qm ³ /s main canal | | Q m ³ /s SC canal | | Qm ³ /s TC canal | | Qm ³ /s Field canal | E _c (%) |
|------------|-------------------------------|-------|------------------------------|-------|-----------------------------|--------|--------------------------------|--------------------|
| | Initial | Final | Initial | Final | Initial | Final | | |
| H1 | 0.835 | 0.830 | 0.185 | 0.155 | 0.128 | 0.102 | 0.102 | 66.47 |
| H2 | 0.830 | 0.728 | 0.182 | 0.148 | 0.125 | 0.110 | 0.110 | 65.17 |
| H3 | 0.828 | 0.408 | 0.177 | 0.149 | 0.128 | 0.100 | 0.100 | 27 |
| M1 | 0.388 | 0.356 | 0.180 | 0.161 | 0.124 | 0.0980 | 0.0980 | 64.85 |
| M2 | 0.380 | 0.344 | 0.178 | 0.156 | 0.123 | 0.0828 | 0.0828 | 66.76 |
| M3 | 0.372 | 0.340 | 0.174 | 0.145 | 0.122 | 0.0822 | 0.0822 | 51.31 |
| T1 | 0.335 | 0.332 | 0.177 | 0.135 | 0.0928 | 0.0820 | 0.0820 | 66.78 |
| T2 | 0.330 | 0.328 | 0.168 | 0.148 | 0.0926 | 0.0791 | 0.0791 | 74.28 |
| T3 | 0.328 | 0.320 | 0.172 | 0.142 | 0.0918 | 0.0782 | 0.0782 | 68.56 |
| Mean | | | | | | | | 61.24 |

The conveyance efficiency of the Ketar III irrigation scheme is better than the Ketar I and Ketar II (Table 4.8). In the case of Ketar I irrigation scheme the main canal was cracked at two places; and one division boxes was non-functional and over-topping of water in tertiary canals was common. However, the values of conveyance efficiency for the three command areas of ketar irrigation scheme are below the recommended value i.e.70% unlined poorly managed main canals (MoAFS, 2002).

Table 4.3. Canal discharges at different points and conveyance efficiency of Ketar II scheme

| Field Code | Qi(m ³ /s) | Qf(m ³ /s) | Qi(m ³ /s) | Qf(m ³ /s) | Qf(m ³ /s) | Qi(m ³ /s) | Field canal(m ³ /s) | Ec(%) |
|------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|--------------------------------|-------|
| H | 0.335 | 0.33 | 0.165 | 0.155 | 0.122 | 0.116 | 0.116 | 87.98 |
| H | 0.33 | 0.328 | 0.158 | 0.14 | 0.12 | 0.108 | 0.108 | 79.26 |
| H | 0.328 | 0.327 | 0.148 | 0.135 | 0.122 | 0.11 | 0.11 | 81.99 |
| M | 0.328 | 0.325 | 0.147 | 0.135 | 0.121 | 0.092 | 0.092 | 69.18 |
| M | 0.325 | 0.325 | 0.148 | 0.134 | 0.123 | 0.0822 | 0.0822 | 60.51 |
| M | 0.325 | 0.322 | 0.144 | 0.13 | 0.12 | 0.082 | 0.0822 | 61.12 |
| T | 0.322 | 0.321 | 0.137 | 0.125 | 0.12 | 0.0815 | 0.0815 | 61.77 |
| T | 0.321 | 0.321 | 0.133 | 0.118 | 0.122 | 0.0771 | 0.0771 | 56.07 |
| T | 0.321 | 0.32 | 0.13 | 0.122 | 0.123 | 0.0762 | 0.0762 | 57.94 |
| M | | | | | | | | 68.43 |

Table 4.4 Canal discharges at different points and conveyance efficiency of Ketar III scheme

| Field Code | Qi (m ³ /s) | Qf(m ³ /s) | Qi(m ³ /s) | Qf(m ³ /s) | Qf(m ³ /s) | Qi(m ³ /s) | Field canal(m ³ /s) | Ec (%) |
|------------|------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|--------------------------------|--------|
| H | 0.335 | 0.33 | 0.163 | 0.15 | 0.12 | 0.115 | 0.115 | 86.88 |
| H | 0.323 | 0.32 | 0.159 | 0.14 | 0.12 | 0.104 | 0.104 | 75.60 |
| H | 0.322 | 0.317 | 0.146 | 0.136 | 0.112 | 0.11 | 0.11 | 90.06 |
| M | 0.325 | 0.324 | 0.142 | 0.135 | 0.111 | 0.092 | 0.092 | 78.55 |
| M | 0.325 | 0.323 | 0.148 | 0.134 | 0.113 | 0.0722 | 0.0722 | 57.49 |
| M | 0.323 | 0.322 | 0.144 | 0.131 | 0.112 | 0.082 | 0.082 | 66.39 |
| T | 0.322 | 0.321 | 0.137 | 0.125 | 0.12 | 0.075 | 0.075 | 56.85 |
| T | 0.321 | 0.318 | 0.133 | 0.118 | 0.122 | 0.0781 | 0.0781 | 56.27 |
| T | 0.311 | 0.31 | 0.13 | 0.122 | 0.121 | 0.0782 | 0.0782 | 60.45 |
| M | | | | | | | | 69.84 |

4.3.2. Application efficiency

The application efficiency of a given irrigation scheme tells us whether the irrigation water is stored in the intended soil profile or lost as surface runoff or/and deep percolation. The application efficiency of selected fields at the three command area of ketar irrigation scheme were found to varied from 52.8 to 73.3.% with an average of 65.61% for ketar I , 44.5% to 71%

with an average 55.87% for ketar II and 57.36% - 75% with an average 67.84 for ketar III. The details of application efficiencies for the selected fields in the three command area of ketar irrigation scheme are shown in Tables 4.5, 4.6, 4.7 and average application efficiency is presented in Table 4.8.

Table 4.5. Measured water depths applied to field, field application efficiency and storage efficiency of Ketar I site command area

| | FC | Q m ³ /s | ET(minute) | Area(m ²) | TV(m ³) | DA(mm) | Ws Zr(mm) | Wn(mm) | Ea (%) | Er (%) |
|---------|------|------------------------|------------|---------------------------|---------------------|--------|--------------|--------|--------|--------|
| ketar I | H1 | 0.012 | 193 | 2400 | 138.96 | 57.9 | 39.5 | 76.5 | 68.22 | 51.63 |
| | H2 | 0.01 | 191 | 2400 | 114.6 | 47.75 | 35 | 76.5 | 73.3 | 45.75 |
| | H3 | 0.012 | 189 | 2400 | 136.08 | 56.7 | 38 | 76.5 | 67.02 | 49.67 |
| | M1 | 0.011 | 187 | 2400 | 123.42 | 51.425 | 36 | 76.5 | 70.00 | 47.06 |
| | M2 | 0.009 | 194 | 2400 | 104.76 | 43.65 | 32 | 76.5 | 73.31 | 41.83 |
| | M3 | 0.011 | 191 | 2400 | 126.06 | 52.525 | 35 | 76.5 | 66.63 | 45.75 |
| | T1 | 0.01 | 195 | 2400 | 117 | 48.75 | 32 | 76.5 | 65.641 | 41.83 |
| | T2 | 0.013 | 201 | 2400 | 156.78 | 65.325 | 35 | 76.5 | 53.58 | 45.75 |
| | T3 | 0.012 | 202 | 2400 | 145.44 | 60.6 | 32 | 76.5 | 52.80 | 41.83 |
| | Mean | | | | | | | | 65.62 | 45.679 |

Where Q is discharge, Fc field code ET elapsed time, TV is total volume, WS is water stored in the root zone W_n water demanded in the root zone Ea is application, and Er is storage efficiency
Appendix Table 5 Measured water depths applied to field, field application efficiency and storage efficiency of Ketar II site command area

Table 4.6. Measured water depths applied to field, field application efficiency and storage efficiency of Ketar II site command area

| | FC | Q m ³ /s | ET(min.) | Area(ha) | TV(m ³) | DA(mm) | WS Zr(mm) | Wn(m m) | Ea (%) | Er |
|----------|----------|------------------------|--------------|--------------|---------------------|--------|--------------|------------|-----------|-------|
| ketar II | H1 | 0.011 | 190 | 2000 | 125.4 | 62.7 | 33.5 | 76.5 | 53.42 | 43.79 |
| | H2 | 0.013 | 195 | 2000 | 152.1 | 76.05 | 39 | 76.5 | 51.28 | 50.98 |
| | H3 | 0.009 | 193 | 2000 | 104.22 | 52.11 | 37 | 76.5 | 71.00 | 48.37 |
| | M1 | 0.011 | 208 | 2000 | 137.28 | 68.64 | 42 | 76.5 | 61.19 | 54.90 |
| | M2 | 0.013 | 197 | 2000 | 153.66 | 76.83 | 42 | 76.5 | 54.66 | 54.90 |
| | M3 | 0.011 | 194 | 2000 | 128.04 | 64.02 | 39 | 76.5 | 60.92 | 50.98 |
| | T1 | 0.012 | 192 | 2000 | 138.24 | 69.12 | 37 | 76.5 | 53.53 | 48.36 |
| | T2 | 0.013 | 197 | 2000 | 153.66 | 76.83 | 34 | 76.5 | 44.25 | 44.44 |
| | T3 | 0.012 | 185 | 2000 | 133.2 | 66.6 | 35 | 76.5 | 52.55 | 45.75 |
| | Me an | | | | | | | | 55.86 | 49.16 |

Where Q is discharge, ET elapsed time, TV is total volume , WS is water stored in the root zone W_n water demanded in the root zone Ea is application ,and Er is storage efficiency

The finding indicates that the application efficiency of ketar I and KetarII command area of the irrigation scheme were better than ketar III command areas. This may be associated with the water use association of ketar I and Ketar II are stronger than that of Ketar II. Generally the average application efficiency of the three command areas of ketar irrigation schemewhich is 63.10 % is a very good results for furrow irrigation (Savva and Frenken, 2002), which is recommended as 50-70% for properly designed furrow irrigation. Kandiah (1981) also reported an application efficiency of 70 % for furrow irrigation.

Table 4.7. Measured water depths applied to field, field application efficiency and storage efficiency of Ketar III site command area

| | FC | Q m ³ /s | ET(min) | Area(h a) | TV(m ³) | DA(m m) | WSZr(mm) | Wn(mm) | Ea (%) | Er (%) |
|--------------|------|------------------------|---------|--------------|---------------------|------------|--------------|--------|--------|--------|
| ketar III | H1 | 0.012 | 170 | 2400 | 122.4 | 51 | 34.3 | 76.5 | 67.25 | 44.83 |
| | H2 | 0.01 | 165 | 2400 | 99 | 41.25 | 31 | 76.5 | 75.15 | 40.52 |
| | H3 | 0.012 | 176 | 2400 | 126.72 | 52.8 | 34 | 76.5 | 64.39 | 44.44 |
| | M1 | 0.011 | 158 | 2400 | 104.28 | 43.45 | 33 | 76.5 | 75.94 | 43.13 |
| | M2 | 0.009 | 162 | 2400 | 87.48 | 36.45 | 26 | 76.5 | 71.33 | 33.98 |
| | M3 | 0.011 | 164 | 2400 | 108.24 | 45.1 | 32 | 76.5 | 70.95 | 41.83 |
| | T1 | 0.01 | 171 | 2400 | 102.6 | 42.75 | 28 | 76.5 | 65.49 | 36.60 |
| | T2 | 0.013 | 177 | 2400 | 138.06 | 57.525 | 33 | 76.5 | 57.36 | 43.13 |
| | T3 | 0.012 | 165 | 2400 | 118.8 | 49.5 | 31 | 76.5 | 62.62 | 40.52 |
| | Mean | | | | | | | | 67.83 | 41.00 |

4.3.3. Deep percolation ratio

Deep percolation ratio indicates the irrigation applied to a field percolates into the soil below the root zone. Higher deep percolation ratio values are indications of over irrigation. As depicted in Table 4.8 average deep percolation ratio on selected plot at Ketar I; Keta II and Ketar II command areas of ketar irrigation scheme were found to be 38.76 %, 31.58 % and 39.54 % respectively. In three command area of the irrigation scheme , there is high deep percolation ratio which indicates over irrigation.

4.3.4. Storage efficiency

The result of storage efficiency of selected fields from the three command area of ketar irrigation scheme were found to vary from 41.83% to 51.630%, with an average storage efficiency of 45.68% in Ketar I , 43.79 to 54.90 with average 49.16 % in Ketar II and 33.98 to 44.83 % with average 41 % in Ketar III. The details of storage efficiency for selected fields and the average storage efficiency in three command areaof ketar Irrigation schemes are shown in

Appendix Tables 4 , 5 and, 6. As shown in Table 2 the storage efficiency at Ketar I and Ketar Command area were slightly greater than Ketar III, but in general the storage efficiency of the three Command area of the schemes were 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.

4.3.5. Overall Scheme Efficiency

The overall efficiency of the scheme is the ratio of water made available to the crop to the amount released at the headwork. In other words, it is the product of conveyance efficiency and application efficiency. In this study the overall efficiencies of the irrigation at command areas of Ketar I, Ketar II and Ketar II of the irrigation scheme were found to be 40.17 %, 38.17 % and 47.38 % , respectively. The details of overall scheme efficiency of the three command area of ketar irrigation scheme were derived from the data shown in Appendix Tables 7, 8, 9 and 10 while the average overall irrigation scheme efficiencies of the three command areas of ketar irrigation schemes are shown in Table 2. The result indicated that the ketar I and Ketar II command areas were relatively poor.

Table 4.8. Average irrigation efficiencies at Ketar irrigation scheme

| Internal indicators | Ketar irrigation scheme sites efficiencies (%) | | |
|----------------------------------|--|----------|-----------|
| | Ketar I | Keatr II | Ketar III |
| Conveyance Efficiency | 61.24 | 68.32 | 69.84 |
| Application Efficiency | 65.61 | 55.87 | 67.84 |
| Deep percolation Ratio | 38.76 | 31.58 | 39.54 |
| Storage Efficiency | 45.68 | 49.16 | 41 |
| Overall Scheme Efficiency | 40.17 | 38.17 | 47.38 |

5. SUMMARY AND CONCLUSIONS

In this study, an attempt was made to evaluate the performance of Ketar irrigation schemes at Tiyo wereda, Oromia Regional State, Central Rift Valley of Ethiopia using internal performance indicators. The internal performance indicators computed were conveyance efficiency, application efficiency, storage efficiency, deep percolation ratio, distribution uniformity and overall efficiency. The assessment of the irrigation efficiencies in Ketar irrigation schemes indicated that the availability of irrigation water is not a constraint and high amounts of water was diverted to the farmer's field. During the study period there was enough water in the Ketar River even during the dry time.

The conveyance efficiency of the three command area of ketar irrigation schemes at all hydraulic levels showed some low values, even in the lined part of the main canal due to lack of regular maintenance such as Ketar I Ketar II, and Ketar III were found to be 61.24 , 68.32%, and, 69.84 % respectively. But there is a room for improvement if the scheme gets regular maintenance. The application efficiency of the three command areas of the irrigation scheme has, however, showed good when we compare with application efficiency of 50-70% for furrow irrigation observed in other African countries.

Based on the assessment made to evaluate the performance of the irrigation scheme, the conveyance efficiency of the three command areas of the scheme at all hydraulic levels showed some low values but the conveyance efficiency at Ketar III command area of the irrigation scheme is better than the Ketar I and Ketar II. The finding indicates that the application efficiency of ketar I and KetarII command area of the irrigation scheme were better than ketar III command areas. This could be due to proper management of the irrigation water management by the farmers association who regularly maintain the canals and use water of appropriate amount.

In general, the overall efficiencies of the irrigation at command areas of Ketar I, Ketar II and Ketar III of the irrigation scheme were found to be 40.17 %, 38.17 % and 47.38 %, respectively. The result indicated that the ketar I and Ketar II command areas were relatively poor.

Based on the assessment carried out, it can be concluded that the ketar irrigation scheme performed better than other similar small scale irrigation scheme of the country, but it cannot be said the Ketar scheme does not need improvement so measures should be taken to improve the performance of the scheme. As there is no shortage of water, the schemes have room to expand and to provide irrigation opportunities to the surrounding community relying on rain fed agriculture. Evaluation of the performance of irrigation systems will help to know the present status of these systems.

6. REFERENCES

Awulachew, Selesh Bekel Aster Denekew Yilma, Makonnen Loulseged, Willibald Losiskandl, Mekonnen Ayana and Tena Alamirew 2007. "Water resource and Irrigation Development in Ethiopia." International Water Management Institute Working Paper 123. Colombo: International Water Management Institute, IWMI,

Degefu, W., 1987. Some aspects of meteorological drought in Ethiopia. In: Glantz, M.H., (Ed.), Drought and Hunger in Africa, Cambridge University Press, Cambridge, pp. 23–36.

Dessalegn Rahmato (1999): Water Resource Development in Ethiopia. Forum for Social Studies, Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization), 1989. Guidelines for Designing and Evaluating Surface Irrigation Systems. Irrigation and drainage paper No.45. FAO, Rome

FAO 1997. "Crops and Drops: Making The Best Use of Water For Agriculture." Rome:

Feyen, J., and Dawit Z., 1999. Assessment of the performance of border and furrow Irrigation Systems and the Relationship between Performance Indicators and System Variables, *Agricultural Water Management*. 40: 353 – 362.

Hussain, I., Hanjra, M.A., (2004). Irrigation and poverty alleviation: review of the empirical evidence. *Irrigation and Drainage* 53, 1–15. <http://dx.doi.org/10.1002/ird.114>.

Kandiah K., 1981. Evaluation of furrow irrigation system for cotton, Melka Werer Research Station, IAR, Ethiopia.

McIntyre, D., 1974. Water retention and moisture characteristics, In: *Methods for analysis of irrigated soil* (Ed. 5 Loveday, J.) Technical communication No.54. Commonwealth Agriculture Bureau, Farnham Royal, England.

MoAFS (Ministry of Agriculture and Food Security, Irrigation Section), 2002. Assessment of Irrigation Efficiency in Traditional Small holder schemes in Pangani and Rufiji Basins, Tanzania.

MoWR (Ministry of Water Resource), 2001. Data collected from different river basin development master plan studies. Planning and Projects Department, Ministry of Water Resources. Addis Ababa, Ethiopia.

MOWR 2002. Water resource Developemnt Programme 2002-2016. Addis Ababa: The FedralDemocratic Republic of Ethiopia Ministry of Water Resource

Pereira, L. and T. Trout, 1999. Irrigation Methods, Land and water engineering, CIGR handbook of agricultural engineering. ASAE.

Peden, D.; Dubale, P.; Tsegaye, E.; Behailu, M.; Tadesse, G.; Gebremedhin,G.,(2002). Community-based irrigation management in Ethiopia: Strategies to enhance human health, livestock and crop production, and natural resource management. International Water Institute \management Institute (IWMI), Addis Ababa, Ethiopia.

P.M. Ingle^{1*}, S.E.Shinde¹, M.S. Mane¹, R.T. Thokal² and Ayare B.L., 2015 Performance Evaluation of a Minor Irrigation Scheme *Research Journal of Recent Sciences* Vol. **4(ISC-2014)**, 19-24 (2015

Savva, A. and K.Frenken, 2002. Planning, Development Monitoring and Evaluation of Irrigated Agriculture with Farmer Participation.FAO, Harare.

Shah, T.; van Koppen, B.; Merrey, D.; de Lange, M. and Samad, M. (2002). Institutional alternatives in African smallholder irrigation: Lessons from international experience with irrigation management transfer. Research Report 60. Colombo: IWMI.

Tesfaye, A.; Bogale, A.;Namara, E.R.;Bacha,D.,(2008). The impact of small-scale irrigation on household food security: The case of Filtino and Godino irrigation schemes in Ethiopia. *Irrigation Drainage Syst* 22:145–158. <http://dx.doi.org/10.1007/s10795-008-9047-5>.

Raghuwanshi, S. and W. Wallender, 1998. Optimal furrow irrigation scheduling under heterogeneous conditions, *Agricultural Systems*, 56: 39 – 35.

Walters, R. and N. Berisavijevic, 1991, Evaluation of irrigation efficiencies (ICID), International Printers: New Delhi

World Bank 2006. "Ethiopia: Managing Water Resources to maximize Sustainable Growth." Country Water Resources Assistance Strategy. Washington DC: The World Bank Agricultural and Rural Developemnt Department.

7. APPENDICES

Appendix Table 1. Canal discharges at different points and conveyance efficiency of Ketar I command area of ketar irrigation scheme

| Field code | Qm ³ /s main canal | | Q m ³ /s SC canal | | Qm ³ /s TC canal | | Qm ³ /s Field canal | E _c (%) |
|------------|-------------------------------|-------|------------------------------|-------|-----------------------------|--------|--------------------------------|--------------------|
| | Initial | Final | Initial | Final | Initial | Final | | |
| H1 | 0.835 | 0.830 | 0.185 | 0.155 | 0.128 | 0.102 | 0.102 | 66.47 |
| H2 | 0.830 | 0.728 | 0.182 | 0.148 | 0.125 | 0.110 | 0.110 | 65.17 |
| H3 | 0.828 | 0.408 | 0.177 | 0.149 | 0.128 | 0.100 | 0.100 | 27 |
| M1 | 0.388 | 0.356 | 0.180 | 0.161 | 0.124 | 0.0980 | 0.0980 | 64.85 |
| M2 | 0.380 | 0.344 | 0.178 | 0.156 | 0.123 | 0.0828 | 0.0828 | 66.76 |
| M3 | 0.372 | 0.340 | 0.174 | 0.145 | 0.122 | 0.0822 | 0.0822 | 51.31 |
| T1 | 0.335 | 0.332 | 0.177 | 0.135 | 0.0928 | 0.0820 | 0.0820 | 66.78 |
| T2 | 0.330 | 0.328 | 0.168 | 0.148 | 0.0926 | 0.0791 | 0.0791 | 74.28 |
| T3 | 0.328 | 0.320 | 0.172 | 0.142 | 0.0918 | 0.0782 | 0.0782 | 68.56 |
| Mean | | | | | | | | 61.24 |

Appendix Table 2 Canal discharges at different points and conveyance efficiency of Ketar II scheme

| Field Code | Qi(m ³ /s) | Qf(m ³ /s) | Qi(m ³ /s) | Qf(m ³ /s) | Qf(m ³ /s) | Qi(m ³ /s) | Field canal(m ³ /s) | Ec(%) |
|------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|--------------------------------|-------|
| H | 0.335 | 0.33 | 0.165 | 0.155 | 0.122 | 0.116 | 0.116 | 87.98 |
| H | 0.33 | 0.328 | 0.158 | 0.14 | 0.12 | 0.108 | 0.108 | 79.26 |
| H | 0.328 | 0.327 | 0.148 | 0.135 | 0.122 | 0.11 | 0.11 | 81.99 |
| M | 0.328 | 0.325 | 0.147 | 0.135 | 0.121 | 0.092 | 0.092 | 69.18 |
| M | 0.325 | 0.325 | 0.148 | 0.134 | 0.123 | 0.0822 | 0.0822 | 60.51 |
| M | 0.325 | 0.322 | 0.144 | 0.13 | 0.12 | 0.082 | 0.0822 | 61.12 |
| T | 0.322 | 0.321 | 0.137 | 0.125 | 0.12 | 0.0815 | 0.0815 | 61.77 |
| T | 0.321 | 0.321 | 0.133 | 0.118 | 0.122 | 0.0771 | 0.0771 | 56.07 |
| T | 0.321 | 0.32 | 0.13 | 0.122 | 0.123 | 0.0762 | 0.0762 | 57.94 |
| M | | | | | | | | 68.43 |

Appendix Table 3 Canal discharges at different points and conveyance efficiency of Ketar III scheme

| Field Code | Qi (m ³ /s) | Qf(m ³ /s) | Qi(m ³ /s) | Qf(m ³ /s) | Qf(m ³ /s) | Qi(m ³ /s) | Field canal(m ³ /s) | Ec (%) |
|------------|------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|--------------------------------|--------|
| H | 0.335 | 0.33 | 0.163 | 0.15 | 0.12 | 0.115 | 0.115 | 86.88 |
| H | 0.323 | 0.32 | 0.159 | 0.14 | 0.12 | 0.104 | 0.104 | 75.60 |
| H | 0.322 | 0.317 | 0.146 | 0.136 | 0.112 | 0.11 | 0.11 | 90.06 |
| M | 0.325 | 0.324 | 0.142 | 0.135 | 0.111 | 0.092 | 0.092 | 78.55 |
| M | 0.325 | 0.323 | 0.148 | 0.134 | 0.113 | 0.0722 | 0.0722 | 57.49 |

| | | | | | | | | |
|---|-------|-------|-------|-------|-------|--------|--------|-------|
| M | 0.323 | 0.322 | 0.144 | 0.131 | 0.112 | 0.082 | 0.082 | 66.39 |
| T | 0.322 | 0.321 | 0.137 | 0.125 | 0.12 | 0.075 | 0.075 | 56.85 |
| T | 0.321 | 0.318 | 0.133 | 0.118 | 0.122 | 0.0781 | 0.0781 | 56.27 |
| T | 0.311 | 0.31 | 0.13 | 0.122 | 0.121 | 0.0782 | 0.0782 | 60.45 |
| M | | | | | | | | 69.84 |

Appendix Table 4 Measured water depths applied to field, field application efficiency and storage efficiency of Ketar I site command area

| | FC | Q m ³ /s | ET(minute) | Area(m ²) | TV(m ³) | DA(mm) | Ws Zr(mm) | Wn(mm) | Ea (%) | Er (%) |
|---------|------|------------------------|------------|---------------------------|---------------------|--------|--------------|--------|--------|--------|
| ketar I | H1 | 0.012 | 193 | 2400 | 138.96 | 57.9 | 39.5 | 76.5 | 68.22 | 51.63 |
| | H2 | 0.01 | 191 | 2400 | 114.6 | 47.75 | 35 | 76.5 | 73.3 | 45.75 |
| | H3 | 0.012 | 189 | 2400 | 136.08 | 56.7 | 38 | 76.5 | 67.02 | 49.67 |
| | M1 | 0.011 | 187 | 2400 | 123.42 | 51.425 | 36 | 76.5 | 70.00 | 47.06 |
| | M2 | 0.009 | 194 | 2400 | 104.76 | 43.65 | 32 | 76.5 | 73.31 | 41.83 |
| | M3 | 0.011 | 191 | 2400 | 126.06 | 52.525 | 35 | 76.5 | 66.63 | 45.75 |
| | T1 | 0.01 | 195 | 2400 | 117 | 48.75 | 32 | 76.5 | 65.641 | 41.83 |
| | T2 | 0.013 | 201 | 2400 | 156.78 | 65.325 | 35 | 76.5 | 53.58 | 45.75 |
| | T3 | 0.012 | 202 | 2400 | 145.44 | 60.6 | 32 | 76.5 | 52.80 | 41.83 |
| | Mean | | | | | | | | 65.62 | 45.679 |

Where Q is discharge, Fc field code ET elapsed time, TV is total volume, WS is water stored in the root zone W_n water demanded in the root zone Ea is application, and Er is storage efficiency

Appendix Table 5 Measured water depths applied to field, field application efficiency and storage efficiency of Ketar II site command area

| | FC | Q m ³ /s | ET(min.) | Area(ha) | TV(m ³) | DA(mm) | WS Zr(mm) | Wn(m m) | Ea (%) | Er |
|----------|----|------------------------|--------------|--------------|---------------------|--------|--------------|------------|-----------|-------|
| ketar II | H1 | 0.011 | 190 | 2000 | 125.4 | 62.7 | 33.5 | 76.5 | 53.42 | 43.79 |
| | H2 | 0.013 | 195 | 2000 | 152.1 | 76.05 | 39 | 76.5 | 51.28 | 50.98 |
| | H3 | 0.009 | 193 | 2000 | 104.22 | 52.11 | 37 | 76.5 | 71.00 | 48.37 |
| | M1 | 0.011 | 208 | 2000 | 137.28 | 68.64 | 42 | 76.5 | 61.19 | 54.90 |

| | | | | | | | | | | |
|--|----------|-------|-----|------|--------|-------|----|------|-------|-------|
| | M2 | 0.013 | 197 | 2000 | 153.66 | 76.83 | 42 | 76.5 | 54.66 | 54.90 |
| | M3 | 0.011 | 194 | 2000 | 128.04 | 64.02 | 39 | 76.5 | 60.92 | 50.98 |
| | T1 | 0.012 | 192 | 2000 | 138.24 | 69.12 | 37 | 76.5 | 53.53 | 48.36 |
| | T2 | 0.013 | 197 | 2000 | 153.66 | 76.83 | 34 | 76.5 | 44.25 | 44.44 |
| | T3 | 0.012 | 185 | 2000 | 133.2 | 66.6 | 35 | 76.5 | 52.55 | 45.75 |
| | Me an | | | | | | | | 55.86 | 49.16 |

Where Q is discharge, ET elapsed time, TV is total volume , WS is water stored in the root zone W_n water demanded in the root zone E_a is application ,and E_r is storage efficiency

Appendix Table 6 Measured water depths applied to field, field application efficiency and storage efficiency of Ketar III site command area

| | FC | Q m ³ /s | ET(min) | Area(h a) | TV(m ³) | DA(m m) | WSZr(mm) | W_n (mm) | E_a (%) | E_r (%) |
|--------------|------|------------------------|---------|--------------|---------------------|------------|--------------|------------|-----------|-----------|
| ketar III | H1 | 0.012 | 170 | 2400 | 122.4 | 51 | 34.3 | 76.5 | 67.25 | 44.83 |
| | H2 | 0.01 | 165 | 2400 | 99 | 41.25 | 31 | 76.5 | 75.15 | 40.52 |
| | H3 | 0.012 | 176 | 2400 | 126.72 | 52.8 | 34 | 76.5 | 64.39 | 44.44 |
| | M1 | 0.011 | 158 | 2400 | 104.28 | 43.45 | 33 | 76.5 | 75.94 | 43.13 |
| | M2 | 0.009 | 162 | 2400 | 87.48 | 36.45 | 26 | 76.5 | 71.33 | 33.98 |
| | M3 | 0.011 | 164 | 2400 | 108.24 | 45.1 | 32 | 76.5 | 70.95 | 41.83 |
| | T1 | 0.01 | 171 | 2400 | 102.6 | 42.75 | 28 | 76.5 | 65.49 | 36.60 |
| | T2 | 0.013 | 177 | 2400 | 138.06 | 57.525 | 33 | 76.5 | 57.36 | 43.13 |
| | T3 | 0.012 | 165 | 2400 | 118.8 | 49.5 | 31 | 76.5 | 62.62 | 40.52 |
| | Mean | | | | | | | | 67.83 | 41.00 |

Where Fc is field code , Q is discharge, ET elapsed time, TV is Total volume , WS is water stored in the root zone W_n water demanded in the root zone E_a is application ,and E_r is storage efficienc

7.2. Appendix. Figures



a



b

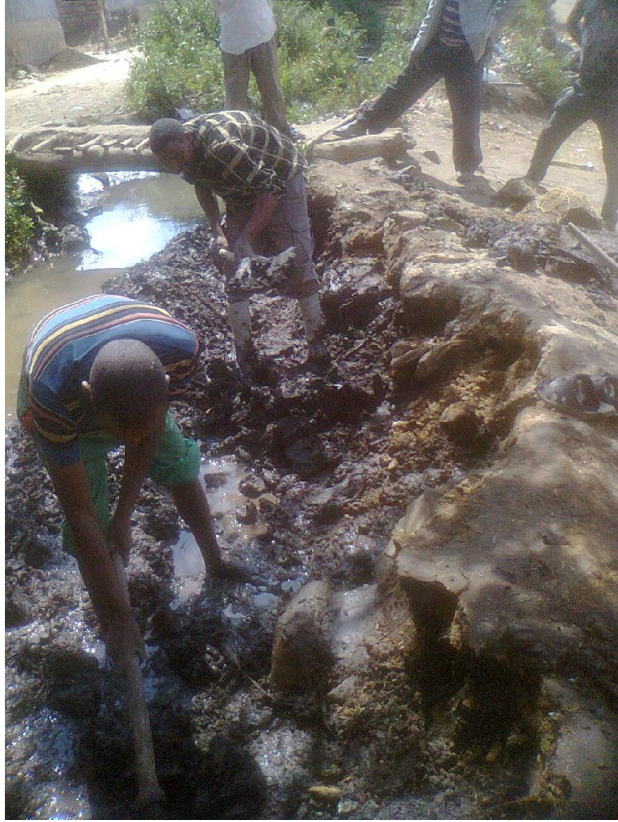
Appendix figure 1 (a) secondary canal at ketar I and b secondary canal at Ketar III



c. broken unlined canal at ketar i

Appendix figure 2. Water use association meeting.





Appendix figure 3 maintenance of canals