



**PERFORMANCE EVALUATION OF WAQEMIYA TIYO AND AWASH MELKASA
IRRIGATION SCHEMES IN EAST SHEWA ZONE, ETHIOPIA**

M.Sc. THESIS

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APRIL, 2023

HAWASSA,ETHIOPIA

**PERFORMANCE EVALUATION OF WAQEMIYA TIYO AND AWASH MELKASA
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A THESIS SUBMITTED TO THE DEPARTMENT OF
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ADVISORS' APPROVAL SHEET

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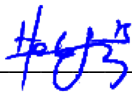
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We, the undersigned, members of the Board of Examiners of the final defense by Alemiye Degefa Tola have read and evaluated her thesis entitled “Performance Evaluation of Waqemiya Tiyo and Awash Melkasa Irrigation Schemes in East Shewa Zone, Ethiopia”, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Irrigation and Drainage Engineering.

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Final approval and acceptance of the thesis are contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department Graduate Committee (DGC) of the candidate’s department.

DEDICATION

I dedicate this thesis manuscript to all my beloved families for their support throughout the day-to-day activity and love and their dedicated partnership in the success of my life.

STATEMENT OF AUTHOR

I hereby declare that this MSc specialty is my original work and has not been presented for a degree in any other university, and all sources of materials used for this thesis have been properly acknowledged.

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LISTS OF ABBREVIATIONS AND ACRONYMS

Bd	Bulk density
°C	Degree celicious
CWR	Crop water requirement
DAs	Development Agents
DU	Distribution uniformity
Dz	Effective root zone
Ea	Application efficiency
Ec	Conveyance efficiency
Eo	Overall irrigation efficiency
Es	Water storage efficiency
ETB	Ethiopian Birr
ET _c	Crop evapotranspiration
ET _o	Reference evapotranspiration
FAO	Food and Agricultural organization
FC	Field capacity
GPS	Geographic Positioning System
Ha	Hectare
IR	Irrigation ratio
IWMI	International Water Management Institute
M ³	Cubic Meter
MoA	Ministry of Agriculture

MoWR	Ministry of Water Resources
MoAFS	Ministry of Agriculture and Food Security
NGOs	Non-Government Organizations
NMSA	National Meteorology Services Agency
OPUCA	Output per unit command area
OPUIA	Output per unit irrigated area
OPUIS	Output per unit irrigation supply
OPUWC	Output per unit of water consumed
PWP	Permanent wilting point
RAW	Readily available water
RIS	Relative irrigation supply
RWS	Relative water supply
SIA	Sustainability of irrigated area
TAW	Total available water
US\$	United State America Dollar
USDA	United State Department of Agriculture
WDC	Water delivery Capacity

ABSTRACT

Performance evaluation of irrigation schemes plays a fundamental role in improving irrigation system of scheme by identifying performance gaps that help to provide appropriate improvement options. Therefore, the aim of this study was to evaluate and compare the performance of Waqemiya Tiyo and Awash Melkasa community managed small-scale irrigation schemes located at Adama District, Oromia, Ethiopia using internal and external performance indicators. For this purpose, primary and secondary data were collected from the schemes and for field data measurements three farmers' fields were selected at the head, middle and tail-end of each scheme. Schemes were evaluated by their own merits with the help of internal performance indicators. Thus, the results of analyses revealed that conveyance, application, storage, overall scheme efficiency and distribution uniformity were 49.0, 56.2, 48.8, 27.5 and 88.2% and at Waqemiya Tiyo whereas, 45.6 53.3, 44.1, 24.3 and 85.8% Awash Melkasa schemes respectively. Then comparison was made using external performance indicators such as water supply, water delivery capacity, outputs and physical indicators. The results obtained revealed that the values of relative water supply and irrigation supply were 0.59 and 0.57 for Waqemiya Tiyo scheme, whereas 0.65 and 0.64 for the Awash Melkasa scheme respectively. Water delivery capacities of Waqemiya Tiyo and Awash Melkasa schemes were 0.60 and 0.37 respectively. The values of output per unit irrigated area were 3962.6 and 2187.3 US\$/ha, and similarly the output per unit command area was 4507.4 and 2479. US\$/ha for two schemes respectively. The output per unit irrigation supply and water consumed were 0.79, 0.45 US\$/m³ and 0.91, 0.57 US\$/m³ for two schemes respectively. Likewise, Physical indicators such as irrigation ratio and sustainability of the irrigated area revealed that 1.14, 1.07 and 1.11, 1.04 for two schemes, respectively. Based on the results obtained, Awash Melkasa scheme was better in terms of relative water supply and irrigation supply. However, Waqemiya Tiyo scheme had significantly better land and water productivity than Awash Melkasa scheme due to used high value crops, agricultural inputs and removal of grass cover and sedimentation from canal systems. As a result, Waqemiya Tiyo scheme was better performing than Awash Melkasa scheme therefore, practices high value crops, sharing their experience with one another to achieve good performance of the schemes.

Keywords: Irrigation scheme, internal indicators, external indicators, efficiency

1. INTRODUCTION

1.1. Background

Nowadays the world's demand for food and fiber is increasing due to the highly growing of the population consequently per capita land and water resources become decreasing. (Ingle et al., 2015). Water is the most limited resource, which is widely used by different sectors like agriculture, domestic and industrial. The competition for this scarce resource is increasing from time to time due to increasing demand from sectors that utilize, which makes less water available for agriculture crop production (Pereira et al., 2009) agriculture is the foundation of economic growth in developing countries (FAO, 2014). In order to address the main challenges caused by food insecurity and rainfall uncertainty for rain fed agriculture, irrigation development is an important means for achieving food self-sufficiency by many countries including Ethiopia (Alamirew et al., 2018).

Irrigation play a significant role in the food security enhancement and economic development of Ethiopia, provided the efficient use of water is required (Haile, 2015). In Ethiopia, irrigation activities for small-scale and large-scale farmlands were practiced for a long time, especially in the Rift Valley of Awash River Basin. Awash River water plays an important role in the socioeconomic and ecological activities (Aregahegn, 2021). Most studies on the SSI schemes focus on technical irrigation performance evaluation but, better availability of water by itself is not a sufficient condition, while several factors determine to maximize agricultural production, thereby improving household food security (Ulsido et al., 2013).

Process measures of performance relate to a system's internal operations and procedures whereas output measures of performance examine the quality and quantity of the system's final

output(Ayana & Awulachew, 2007). As the study outlined in the major part of Ethiopian, irrigated agricultures are served by the surface canal irrigation system, and unfortunately, the majority of operational irrigation schemes are characterized as poor performance level (FAO, 2007; Awulachew *et al*, 2007 and Awulachew & Ayana, 2011). The performance of the existing irrigation schemes in Ethiopia was estimated at an average of 36% below design capacity (Awulachew *et al.*, 2010).situations such as poor operation, maintenance, and field irrigation water management practices, faults in planning, design, and implementation, absence of continuous improvement initiatives and performance monitoring mechanisms, and lack of managerial and operational rules are causes of the poor performance of irrigation schemes (Awulachew & Merrey, 2007; Cakmak & Beyr, 2004; Lambisso, 2008).

The comparative estimate is 40 percent or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff (Tesfaye & Jemal, 2020).International Water Management Institute (IWMI) has proposed a minimum set of indicators for comparative performance studies in irrigation systems. It is mainly focused on water, land and crop production in different systems. Such evaluation using comparative indicators can give the response to which irrigation system utilizes limited water and land resources optimally (Ingle et al., 2015).With this regards the evaluation conducted in waqemiya Tiyo and Awash Melkasa irrigation schemes having objective to identify the performance level in accordance with Internal and External indicators since in 2021/2022 irrigation season.

1.2 Statement of the Problem

One pressing resource management challenge particularly in Ethiopia in general is the poor performance of small-scale irrigation systems (Seleshi et al., 2010). While the area under irrigation in the region is low. In Adama District some modern and several traditional irrigation systems are operating from Awash River. However, many problems and challenges will come up with the development of the irrigation if there is no strong management and continuous performance evaluation (FAO, 1996).

Similarly, In Awash Melkasa and Waqemiya Tiyo irrigation schemes like the farmers spend their time in cleaning canals, which they have to do every season before irrigation started, unnecessary grass cover and stagnation of irrigation water canals, poor maintenance practices, due to lack of frequent training for water application and management, head users apply more water than crop water requirement, unbalanced crop growth, excessive leaching losses in areas, conflicts among irrigation water users. This affects the efficiency of agricultural output performance and also creates difficulties for an equity water distribution. All these collective effects put the performance of the schemes under question and the feeling of the users about the schemes decline negatively.

Only about 10 - 12% of the total potential is currently under production using traditional and modern irrigation schemes (MOA, 2011). Though the area under irrigation is very small, it needs continuous performance evaluation to identify performance gap, causes for the gap and made improvement measures Thus, calls for a needs to conduct study on the performance Evaluation of Waqemiya Tiyo and Awash Melkasa irrigation schemes located in East Shewa Zone Adama District with the following general and specific objectives.

1.3. Objective of the Study

1.3.1. General Objective

The general objective of this study was to evaluate the performance of Waqemiya Tiyo and Awash Melkasa irrigation schemes based on Internal and External performance indicators.

1.3.2. Specific Objectives

The specific objectives of the study were:

- ❖ To evaluate the performance of schemes using Internal performance indicators that help to evaluate irrigation schemes performance at the field level
- ❖ To compare two irrigation schemes using External performance indicators
- ❖ To suggest possible improvement options

1.4. Research Questions

1. What was the performance level of selected small scale community managed irrigation schemes using internal performance indicators?
2. What were the performance gaps of the schemes and where to improve the Performance of each irrigation schemes?
3. Which irrigation scheme was performing relatively better?

1.5. Scope of the Study

This study specifically focused on the analysis evaluation of irrigation schemes and for sustainability in irrigation schemes that contribute to better service. Based on the available data, particularly focused on the performance evaluation of each irrigation scheme based on quantified external and their own merits by using internal performance indicators. However, runoff ratio were not evaluated in this study, because farmers practiced closed end furrow in study areas. the analysis of the existing schemes in Adama woreda shall do and possible mitigation measures have recommended.

1.6. Significance of the Study

This study is believed to contribute by narrowing the information gap regarding the performance level of the schemes and water management practice in both irrigation schemes. Thus to serve as a source of additional information for use by policymakers, irrigators, WUAs, planners, and local community to know the performance level of the scheme and identify areas that need improvement during the planning of an irrigation scheme management plan. And environmental effects of small-scale irrigation need to be well documented for planning purposes. Therefore, this study is providing some direction to the system managers, farmers, researchers, and policymakers for a better understanding of the current performance level of the schemes. And enable them to identify performance gaps in irrigation management policies relative to the other scheme and to identify an area of intervention to meet the high increase of demand for limited land and water resources relatively. Moreover, it provides information on each irrigation scheme to learn each other and take lesson from best practices for improvement.

2 LITERATURE REVIEW

2.1. Irrigation Development in Ethiopia

Irrigation development is vital to the sustainable and reliable agricultural developments in Ethiopia. Subsistence dominated smallholder farmers' economy can be improved through the use of irrigation in the Ethiopian agriculture (MoA, 2011b). Similarly, making use of irrigation agriculture is going to be a means for increased agricultural production to meet the growing food demands of rapid population growth. Irrigation development in Ethiopia can be considered as a cornerstone of food security and poverty reduction tool as it has a power to stimulate economic growth and rural developments (Hagos et al., 2009 and Jambo *et al.* 2021), as cited by (Haile and Kasa 2015). As a result, irrigation infrastructures are increasing year after year, which show country wide positive development implications and experiences in small and large scale irrigation schemes.

In Ethiopia, only 10% of the estimated potential irrigable land is actually irrigated (Gebremedhin and Pedon, 2002) and 2% of cultivated lands are irrigated (MoWR, 2001). Similarly, irrigated agriculture comprises only 3% of the total national food production (Bacha et al., 2011). That is why irrigated agriculture is far from satisfactory, despite the considerable investment, public interest, and strategic support of the government. (Belay and Bewket 2013) explained that irrigation water is critical to poverty alleviation through increased production in rural areas so as to improve food security and rural livelihoods. Smallholder irrigation has recently received significant focus from local governments to enable farmers to cultivate crops twice or more per year (Bacha et al., 2011).

2.2. Community Managed Irrigation Schemes in Ethiopia

The government of Ethiopia gives special attention to the management aspect of the small-scale irrigation schemes by considering management play a great role on improvement of the performance of irrigation schemes (MOA 2011). Establishing appropriate water management institutions and building capacity of water management organizations could help for efficient and equitable distribution of irrigation water for beneficiaries, thus contributing to maximize production without bringing adverse impacts on the natural resource as result sustainability of the scheme may been sure (Mastewal 2015). Stated that the success and failure of irrigation schemes depend on the governance capacity and accountability (Awulachew 2010). also argued that Ethiopia faces four key technical, socio-economic, institutional and environmental challenges to meet its ambitious irrigation development potential. Accordingly, to overcome the above challenges good management aspect and structured organization is necessary. Irrigation development is crucial to improving small holder livelihood and in come in Ethiopia. If supported by the strong and sound management of the scheme. On another hand, also stated that the agricultural water management is essential to increase agricultural productivity to eradicate poverty, improve the economy, and reduce degradation of the surrounding environment.

2.3. Evaluation of Irrigation Scheme Performance

Performance evaluation of irrigation schemes is meaningful if related to certain management objectives that are defined for a given situation (Walker and Skogerobe, 1987). Numerous performance evaluation indicators have been developed, that is 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 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, environment, management, physical indicators, which are regarded as external indicators Bos, (1997).

2.4. Performance Gaps in Irrigation System

The identification of any performance gap in the goal achieving process and amending the situation is necessary for the irrigation performance improvements. Hence, managers at different levels should identify performance gaps, find the causes for the gap and take corrective measures to cure the poor targeted performances. There are four potential kinds of performance gaps in irrigation system performances. Douglas and Juan, 199.

Implementation Performance Gap: This type of gap is when a difference arises between how management procedures are supposed to be implemented and how they are implemented. This includes such problems as how people adjust gates, maintain canals and report information. To mitigate this kind of problem in irrigation the strategies of implementing operational procedures, consistent supervision or monitoring of the system, and awareness creating techniques should be changed. Training the farmers and developing their capabilities regarding the operation, maintenance, and overviews of system management are vital roles in irrigation systems.

Technological Performance Gap: This is when the physical infrastructure cannot deliver the amount of a given hydraulic performance standard. The normal solution to amend the technological performance gap is changing the type of irrigation system, proper design, or changing the condition of physical infrastructure and/or maintenance of the non-functional infrastructures.

Achievement Performance Gap: This performance gap is the variation among management targets and actual achievements. Such problems are generally addressed either by changing the

objectives or increasing the capability of management to achieve intended targets through increasing accessibility to management or reforming organizations' setups in irrigated agriculture.

Impacts of Management: This is the state of varying what people think should be the ultimate effects of the use of irrigation and what results. These are gaps in impact performance and include such measures as agricultural and economic profitability of irrigated agriculture, productivity from the amount of irrigation water, poverty alleviation, and environmental problems. If management procedures are being followed and targets are being achieved, but ultimate impacts are not as intended, then the problem is not that the managing organization has performed badly, since these effects are generally beyond its direct control and so, this is the problem of policy (Douglas and Juan 1999).

2.5. Performance Indicators

Performance indicators measure the value of a particular item such as yield or canal discharge and must include a measure of quality as well as of quantity and be accompanied by appropriate standards or permissible tolerances (Murray-Rust and Snellen, 1993). Performance indicators can be broadly categorized into internal and external indicators. However commonly 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 (Jurriens et al., 2001). Internal indicators, which relate performance to internal management targets, external indicators enable comparison between different regions, different infrastructure, and management types, and different environments. Moreover, the trend in performance of a specific scheme can be compared over time. Internal irrigation performance is also linked to farmers' level of satisfaction

by some authors (Ghosh et al., 2005). 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. A major purpose of this type of evaluation 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 (Molden et al., 1998). Internal indicators do not lend themselves well to cross-system comparison. This is due to several reasons. First, internal processes of irrigation systems vary widely from system to system, so that performance indicators are tailored to meet system-specific needs. Second, indicators related to irrigation processes tend to be data intensive and it is often difficult, time-consuming, and expensive to obtain complete data sets. Third, assumptions about relations between internal processes and outputs may not be valid. It is often assumed that meeting a target will improve output in terms of agricultural production or net benefit to farmers.

2.5.1. External Performance Indicators

External performance indicators examine and compare the system's output and bulk impacts of irrigated agriculture among irrigation schemes and/or within the same scheme over time helps to give insight into how productive and efficient land and water resources are used for irrigated agriculture. Moreover, the external performance indicators are used to evaluate outputs and impacts of intervention in individual systems and compare the performance of a system over time, and at different system levels (Molden *et al.*, 1998).

2.5.2.1. Water Delivery Performance Indicators

(Molden *et al.* 1998) proposed major water delivery performance indicators such as relative water supply, relative irrigation supply, and water delivery capacity. They are used to measure the irrigation adequacy of the irrigation schemes, meaning they measure whether or not the maximum crop water and irrigation water requirements are satisfied by supplied irrigation water and present canal capacity at the system head.

I. Relative Water Supply

It is the most comprehensive indicator to examine whether or not the applied water from all sources tightly meets the crop demands over a specific period of crop grown in a specific area (Levine, 1982). Molden *et al.*, (1998) and Cornish, (2005) recommended that a unit value for relative water supply is better than higher or lower values. Because, its value of more than one indicates extra water is applied to the root zone beyond plant demands while its value below one indicates the water supplied does not tightly satisfy the crop demands (Raghuwanshi and Wallender, 1998). (Solomon 2016) conducted a study on performance evaluation in Jari and Aloma small-scale irrigation schemes, Tehuledere district, Ethiopia. This study reported that the relative water supply values were almost equal to one. This study concluded that the water supplied was tightly sufficient for the crop water demand. Shenkut (2015) carried out a study on a comparative performance assessment of Shina Hamusit and Selamko irrigation schemes in Ethiopia. This study reported that the results of relative water supply were 1.55 and 1.87 respectively for Shina Hamusit and Selamko irrigation schemes. This means that the water applied was beyond the crop water demand. Adane *et al.* (2020) conducted a study on the performance assessment of upper Blue Nile small-scale irrigation schemes in Ethiopia. The study reported that the values for relative water supply were 6.21, 5.23, 4.11, and 3.56 respectively for

Ashar, UpperQuashine, Zuma-1, and Zuma-2 irrigation schemes. This study concluded that excess water was delivered to the field beyond crop water demand causing water logging problems, and then, plant root aeration.

II. Relative irrigation supply

According to Awulachew and Ayana (2011), relative irrigation supply examined the irrigation schemes as to whether or not the total applied irrigation water satisfied the irrigation water demand (i.e. net irrigation requirement). The unit value of relative irrigation supply is expected from good performing irrigation schemes and that indicates the applied irrigation water is sufficient tightly to meet crop irrigation demand, i.e. neither surplus nor deficit. If its value is greater than one, the excess irrigation water is applied that is beyond the irrigation water demands while if its value is less than one, the water applied does not satisfy the irrigation demand (Molden *et al.*, 1998). Agide (2012).conducted a study on a comparative performance assessment of community-managed Golgota and Wedecha (Godino sub-system and Gohaworki Sub-system) irrigation schemes in Ethiopia. The study reported that the relative irrigation supply for Golgota, Godino sub-system, and Gohaworki sub-system irrigation schemes were 3.17, 1.90, and 1.20 respectively. This study concluded that irrigation supply at Godino sub-system was well matched to the demand of than Golgota scheme and Gohaworki sub-system. But, excess water was applied in Golgota irrigation scheme and Gohaworki sub-system schemes. The reasons were farmers themselves are responsible for the volume of water diverted from the river and there is no irrigation water fee in Golgota scheme and the absence of water control gates at the headwork of Gohaworki sub-system schemes. Agide *et al.* (2016) conducted a case study on the analysis of water delivery performance of small-scale irrigation schemes in terms of diversity and lessons across schemes, typologies, and reaches in Ethiopia. This study concluded that the relative

irrigation supply for semi-modern irrigation scheme was responded to the highest, but, the traditional scheme replies the lowest value due to disparities in the water supply at irrigation reaches.

III. Water Delivery Capacity

It is an indication of the degree to which irrigation infrastructure constrains the cropping intensities by comparing the canal conveyance capacity to peak consumptive demands (Molden *et al.*, 1998). This indicator addresses the question of whether the system has been designed and constructed in such a way that able to meet the peak water demand of the irrigated crops in a particular growth period (Kloezen and Garces-Restrepo, 1998). Molden *et al.*, (1998) recommended that the water delivery capacity value must be one for good performing irrigation schemes. However, for the conclusion, it should be interpreted in the context of the irrigation system and in conjunction with the other indicators. Zinabie (2018) conducted a case study on the performance evaluation of Golina small-scale irrigation in North Wollo, Ethiopia. This study reported that the main canal has 82% of design capacity due to maintenance problems and water shortage. According to Samad *et al.* (2000), in a study on water delivery performance in the Doroodzan irrigation scheme in Iraq, the system could not deliver water according to the real crop water requirement. Janvier and Blessing (2020) conducted a case study on the performance evaluation of Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes in Rugeramigozi Marshland in Rwanda. This study reported that the existing irrigation canals' capacities were sufficient to meet the irrigation water requirements at the peak demand period.

2.5.2.2. Irrigated Agriculture Output Indicators

According to (Molden *et al.* 1998), the irrigated agriculture performance indicators are evaluators of land and water productivity of irrigated agriculture. Where water is a constraining

resource, output per unit of water may be more important, while if the land is a constraint relative to water, output per unit of land may be more important. The land productivity shows the response of each cropped area to generating gross return within the available water and is the effectiveness of land productivity. While the water productivity describes the outcome gained through using a meter cube of applied water and it is the effectiveness of water productivity.

Agide (2012) conducted a study on a comparative performance assessment of Golgota and Wedecha irrigation schemes in Ethiopia. This study reported that in terms of land productivity Golgota irrigation scheme could be considered the benchmark in the region due to more intensive irrigation and better investment; however, it had poor water productivity due to uncontrolled water diversion and the absence of irrigation fees. While Godino sub-system of Wedecha irrigation scheme could be benchmarked in the region for water productivity. Mintesinot *et al.* (2004) conducted a study on the performance evaluation of community-managed irrigation schemes in Tekeze basin in Ethiopia during two cropping seasons. This study reported that the higher values of land productivity were obtained during the first season than in the rest of the seasons, because, in the first season most of the irrigated land was cultivated by high-value crops (Tomato, Onion, and Papers).

Janvier and Blessing (2020) conducted a study on the performance evaluation of Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes in Rwanda. This study reported that low land productivity was obtained for two irrigation schemes. However, the water productivity was superior for Rugeramigozi 2 than Rugeramigozi 1 scheme due to the adoption of deficit irrigation strategies in Rugeramigozi 2 scheme.

2.5.2.3. Physical Performance Indicators

Physical indicators are related to the changing or losing irrigated land in the command area for different reasons. Among these, 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 sustainability of irrigated area are the two main indicators as illustrated by (Yercan et al. 2004) and (Şener et al. 2007).

I. Irrigation Ratio

Irrigation ratio is the ratio of currently irrigated area to irrigable command area. It tells the degree of utilization of the available command area for irrigated agriculture at a particular time. Shortage of irrigation water, lack of irrigation infrastructure, lack of interest on irrigation due to less return, reduced productivity due to problems such as salinization and waterlogging, etc., could result in underutilization of land. On the other hand, cropping intensity, a ratio of annual cropped area to nominal area is indicative of annual land utilization.

According to Burton et al. (2000), cropping intensities from 100 to 200% are considered good; whereas an inferior figure is low.

II. Sustainability of Irrigated Area

Sustainability of irrigated area is the ratio of currently irrigated area to initially irrigated area (Bos, 1997). It is a useful indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator would mean the abandonment of lands, which were initially irrigated and hence, indicate contraction of the irrigated area over time. On the other hand, the values higher than unity indicate expansion of irrigated area and this imply more sustainable irrigation.

2.5.2. Internal Performance Indicators

Internal performance indicators examine the system's internal operations and procedures that relate performance to management targets by analyzing the efficiency, uniformity and adequacy of the irrigation system (Molden *et al.*, 1998). Thus, they are used to assess the performance of irrigation schemes following a goal-oriented model approach (Kloezen and Garces-Restrepo, 1998). They help the irrigation managers to monitor every managerial and operational performance (Murray-Rust & Snellen, 1993). But doesn't help in assessing the importance of irrigation in a given system, at separate system levels, and with separate irrigation water sources relative to other systems. Moreover, the internal performance indicators address how the input (water) is used, without providing the information on what wider hydrological, agricultural, economic, social, and environmental impacts the inputs have led to. The common irrigation efficiency terms (conveyance, field application, water storage, and overall irrigation efficiency), uniformity, and recently complementary terms (runoff ratio, deep percolation ratio) are used as internal performance indicators for on-field level irrigation system evaluation and also put as the remarkable primary performance indicators Murray-Rust & Snellen,(1993).

2.5.2.1. Conveyance Efficiency

Conveyance efficiency is an indicator which measures irrigation water is normally conveyed from a water source to the farm or field through natural drainage ways, constructed earthen or lined canals, or pipelines. Many conveyance systems have transmission losses, meaning that water delivered to the farm or field is usually less than the water diverted from the source. Water losses in the conveyance system include canal seepage, canal spills, evaporation losses from canals, and leaks in pipelines (Irmak et al., 2011). Conveyance loss consists mainly of operation losses, evaporation and seepage into the soil from the sloping surfaces and bed of the canal.

Evaporation loss in irrigation networks is generally not taken into consideration (Xie et al., 1993). The seepage loss in the irrigation canals accounts for the major portion of water conveyance loss, for example, Baden horst et al., (2002) reported that 98.4 % was due to conveyance loss and only 0.3 percent is from evaporation. High seepage in canals leads to an increase in the water table of the irrigated area resulting in yield reduction. Moreover, the loss of irrigation water through seepage in canals reduces the share of water availability for the newly irrigated area. Under such conditions, improving irrigation canals by lining minimize the water loss through seepage (Kumar et al., 2008). In addition to this with proper soil compaction techniques, steady states loss rates in earthen channels can be reduced even more than 50 %. Jadhav et al. (2014) reported that overall conveyance efficiency of the lined, unlined section of the main canal and field channel was 75.1, 52.3 and 34.8 % respectively at Panchnadi Minor Irrigation Project. Moreover, it has been reported that management interventions of converting the unlined canal network sections into lined sections could improve conveyance efficiency by up to 75 %. Conveyance efficiency at main unlined canal of Selgie irrigation scheme, which is ranges from 69 % to 81 % as reported by (Menelik 2008).

2.5.2.2. Field Application Efficiency

At the field level, the irrigation water may lose by deep percolation, tail water runoff, evaporation, and seepage losses, especially in surface irrigation systems and that might affect applied irrigation water. Thus, field application efficiency examines the stored water in the root zone relative to the irrigation water applied to the field (FAO, 1989). The study conducted on-field application efficiency of the irrigation system states that their attainable values vary greatly with irrigation system, type, and management (Solomon, 1988). The same source suggested the field application efficiency for the basin, border, and furrow irrigation were in the ranges of 80-

90%, 70-85%, and 60-75% respectively. Moreover, Irmak *et al.* (2011) explained the potential application efficiency values of (45-65), (55-75), (60-80), (40-60), (65-80), and (60-90) percent for well-designed and well-managed conventional furrow, surge furrow, tail water reuse furrow, paddy basin, precision level basin, and border irrigation system respectively. Irrigation management improves field application efficiency by 5-20% by applying the right depth of water in the right place at the right time (Edkins, 2006).

2.5.2.3. Water Storage Efficiency

In any irrigation scheme, the irrigation practices could satisfy the water requirement of the soil to compensate for the moisture depleted by evapotranspiration. Irrigated fields may have good field application efficiency, yet the irrigation practice may be poor. Such problems may be because of poor water storage efficiency, as the water required before irrigation may not store in the root zone during irrigation (Garg, 2006). The storage efficiency explains how well the system stored water in the plant root zone to meet crop water needs. In another word, it indicates the adequacy of the operating irrigation schemes. High storage efficiency means that the irrigation brings the soil moisture to field capacity. It might reduce the crop yield since it reflects the degree of soil moisture stress. The recommended water storage efficiency for furrow irrigation systems is 63% (Raghuwanshi and Wallender, 1998). Jibril *et al.* (2017) conducted a study on the performance evaluation of Badeggi irrigation scheme in Niger state Nigeria. This study reported that 70% of water storage efficiency was poor and the reason for this was the low water-holding capacity of the soil and excess seepage loss. However, Yemendwosen & Zinabu (2015) conducted a case study on the evaluation of irrigation water management at sugarcane production in Wondo Genet in southern Ethiopia. This study reported a better average water storage efficiency of 94.96%.

2.5.2.4. Irrigation Uniformity

The fair distribution of irrigation in the field is affected by many factors like the method of irrigation, topography, soil infiltration characteristics, furrow types, field length, irrigation system pressure, and flow rate (Irmak *et al.*, 2011). Accordingly, for surface irrigation, the fair distribution of irrigation water throughout the field is affected by: (i) differences in opportunity time for irrigation caused by advance and recession, (ii) spatial variability of soil-infiltration properties, and (iii) non-uniform grades of the irrigated fields. The most commonly used irrigation water uniformity indices considered in surface irrigation systems are distribution uniformity and Christian's uniformity coefficient (Zerihun *et al.*, 1997). Most of the time Christian's uniformity coefficient is recommended for stationary sprinklers irrigation systems (Irmak *et al.*, 2011). The distribution uniformity more commonly helps to examine the irrigation water distribution over the field in surface irrigation systems, but it is also recommended for micro and sprinkler irrigation systems.

The studies conducted by Eisenhauer (1997) and Irmak *et al.* (2011) reported that the distribution uniformity values of $\geq 60\%$ indicated the irrigation water is fairly distributed throughout the irrigated field. Moreover, Raghuwanshi and Walender (1998) recommended the irrigation uniformities for advanced furrow system was 70%. Guesh (2017) conducted a study on comparative performance evaluation of Maishawsh and Midmar irrigation schemes in Meren sub-basin, Ethiopia. This study reported good distribution uniformities for Maishwsh and Midmar irrigation schemes, its values were 94.21 and 93.4% respectively.

2.5.2.5. Overall Irrigation Efficiency

It represents the effectiveness of the entire physical system and operating decision in delivering irrigation water from a water supply source to the target crop demands (Irmak *et al.*, 2011). It includes the conveyance efficiency in water delivery and distribution systems, and field application efficiency at the field level (Rai *et al.*, 2017). According to FAO (1989), the overall irrigation efficiency of 50–60% is good; 40% is reasonable, while between 20–30% is considered to be poor. Savva and Frenken (2002) reported that for African irrigation schemes the overall irrigation efficiency is commonly observed in the range of (40-50%). In Ethiopia, various studies reported the overall irrigation efficiencies values less than this range, for example, Muhammedziyad *et al.*, (2018); Eticha (2011); Tadesse (2017); Zinabie (2018), and Minchil (2019) reported the overall irrigation efficiencies were 35.9%, 28.6%, 25.89%, 34.97%, and 35.36% respectively.

3. MATERIAL AND METHODS

3.1. Description of the Study Area

3.1.1. Location

This study was conducted in Adama District. Adama forms a special zone of Oromia and is surrounded by East Shewa zone. at a distance of 100km southeast direction of Addis Ababa. The city sits between the base of an escarpment to west, and the Great Rift Valley to the east. The study areas are located at Latitude $8^{\circ}24'14''$ to $8^{\circ}44'55''$ N and $39^{\circ}04'19''$ to $39^{\circ}25'39''$ E Longitudes, and It covers an area with altitudinal range from 1500-2300 m.a.s.l area in two irrigation schemes receives a mean annual rainfall 935.8mm (NMSA). The main source of water in study area is Awash River.

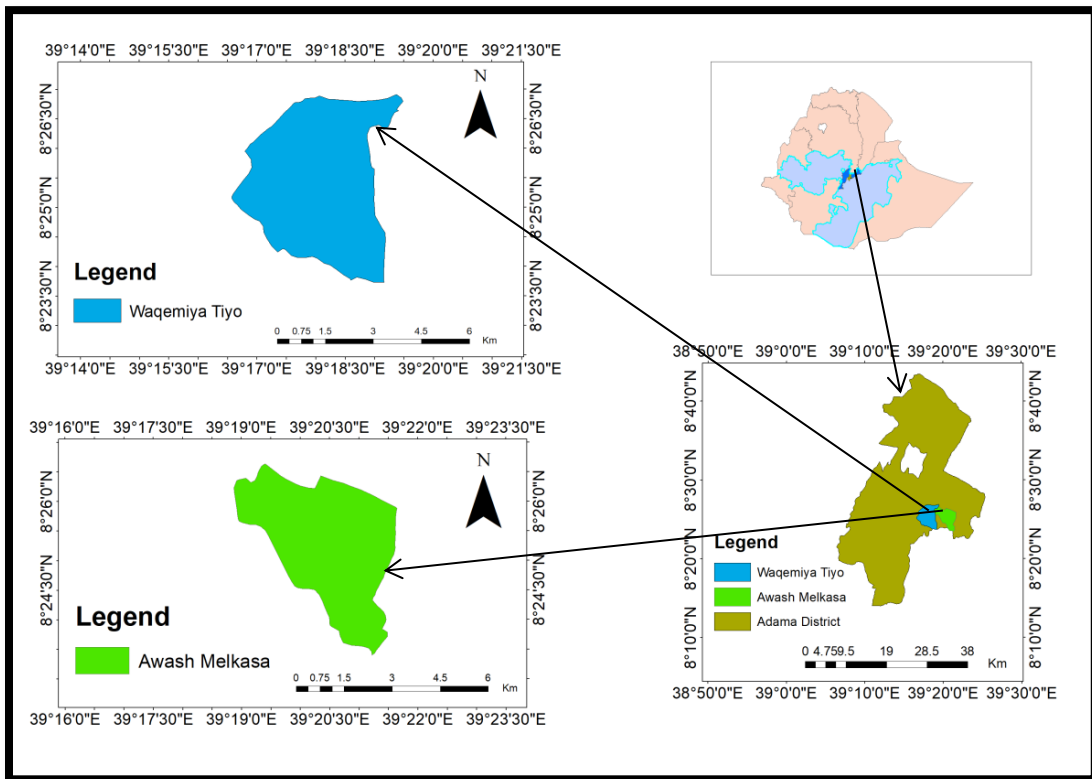


Figure 3. 1: Location Map of the study area

3.1.2. Climatic Water Balance of the Study Areas

Climatic data were collected from National Meteorology Services Agency (NMSA). The rainfall data for both the study areas was obtained from nearby Melkasa station and it has the same Agro-climatologically condition with study areas. As indicated in Figures 3.2 below, the monthly rainfall is higher than the monthly reference evapotranspiration between the end of May and the last half of October. This indicated that, no need for irrigation application during this season. Since the monthly reference evapotranspiration is higher than monthly rainfall, the irrigation is highly important during January; February, March, November, and December. However, in April, May, and October supplementary irrigation may support rainfall shortage.

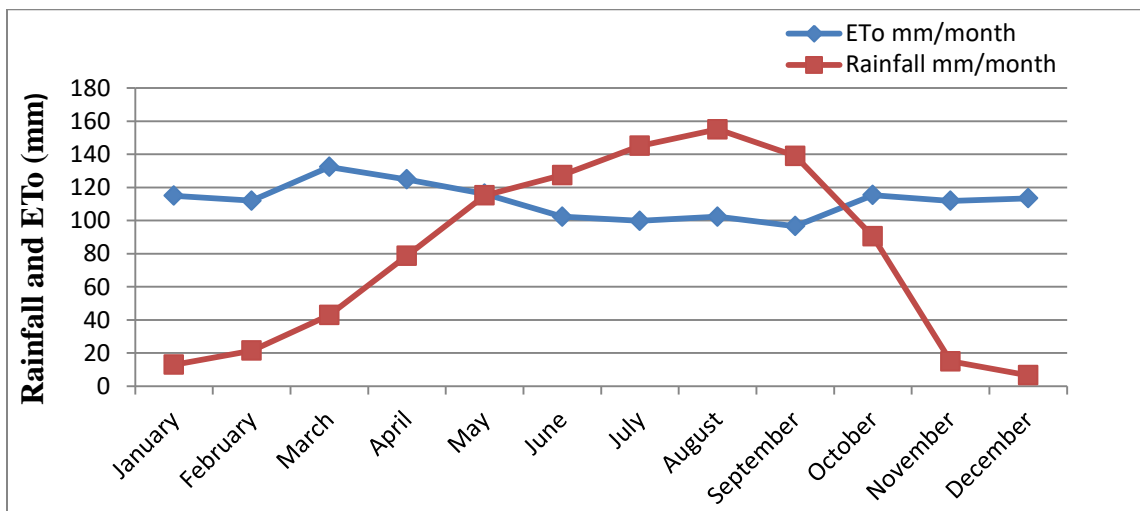


Figure 3. 2: Climatic water balance in study area

3.2. Description of Two Irrigation Schemes

In order to illustrate the potential use of irrigation performance indicators in evaluating efficiency of irrigation systems, two schemes in the Awash drainage basin were considered. The criteria for consideration of two irrigation schemes were based on the proximity to Melkasa

Research Center, availability of secondary data. Both schemes near to each other and they have similar farmland management, soil types and climatic conditions.

3.2.1. Awash Melkasa Irrigation Scheme

Geographically, it found between 8°24'20"N and 39°19'13"E within the altitudinal range of 1520 to 1540m.a.s.l. the scheme is located at about 15km South of Adama Town. The water source for Awash Melkasa irrigation scheme is Awash River. It was constructed by Oromia irrigation development authority in 2007 E.C. The irrigation schemes were managed by communities which initially designed to irrigate 150ha. The total length of the main canals was around 800m. The main canal was in poor condition because of the earthen type canal. Farmers use field canals that are connected directly to the main canals. Dominant soil texture in the command area is loam soil. The major irrigated crops grown in this area is vegetables like tomato, onion, cabbage, tobacco, potato, pepper Having 47, 27, 5, 6, 11 and 3% areal coverage respectively, the frequency and depth of irrigation event practices in the area differ depending on the types of crops.



Figure 3. 3: Awash Melkasa irrigation scheme

3.2.2. Waqemiya Tiyo Irrigation Scheme

Geographically, it lies within 8°24'30"N latitudes and 39°18'28"E longitudes. It was established in 1998 E.C. by the Federal Government of Ethiopia. 17km away from Adama Town to South direction. The main canal is 600m long and made of earth, except at the head, where a lined canal was built for up to 350m. Farmers use the furrows in the field to drain directly onto the canals. Irrigation schemes were managed by communities which initially designed to irrigate 200ha. dominant crops of the area grown under irrigation in this scheme are tomato, onion, cabbage, pepper, potato and tobacco having 55, 24, 10, 3, 7 and 1 % areal coverage respectively. Most of the products are sold to wholesalers coming from Adama Town near the scheme area while other supplied the products directly to the market nearby the cultivation areas. the actual beneficiary of the scheme is increased from 412 households to 807 during design which are 584 male and 223 female beneficiaries at this time.



Figure 3. 4: Waqemiya Tiyo irrigation scheme

3.3. Materials Used

the material used for this study include: Tape meter (was used to measure the length of the canal and area of field plot), Stop watch (to know the time taken water passing through the Parshall flume and time taken the floating object move on canal water), 3-Inch parshall flume (used to measure depth of water or discharge at field level), Water level (to check slope of parashall flume), Staff gauges (to insert it to measure water depth), Hammer (to hit core sampler, Four stakes (to fix measuring place), Floating object One liter empty bottle, leaf (water flow velocity measurement), GPS (to measure area initially designed Currently irrigated land and coordinates of each measurement points to generate the study area map location), Augers (to dig soil samples for soil moisture texture analysis) Plastic bags (to take soil samples to laboratory), Double ring infiltrimeter (to measure infiltration rate of water in to soil), Analytical balance (used to measure weight of soil moisture i.e. at wet and dry condition of Soil), Oven dry (oven was used by high-forced thermal convection (105°C) to dry soil sample, Phone camera (to take image of the Study activity), Microsoft Excel 2010 spreadsheet was (used for data analysis), ArcMAP 10.3 and Google Earth (were used for study area delineation), and CROPWAT 8.0 was used for determining crop water requirement, irrigation water requirement, and irrigation scheduling.

3.4. Field Experimental Layout

To collect and measure the relevant data at the field level, the representative three farmers' fields were selected at the head, middle and tail end water users in each irrigation scheme based on land tenure arrangements, water management practices, the willingness of the farmers, and main canal reach that utilize the irrigation water.

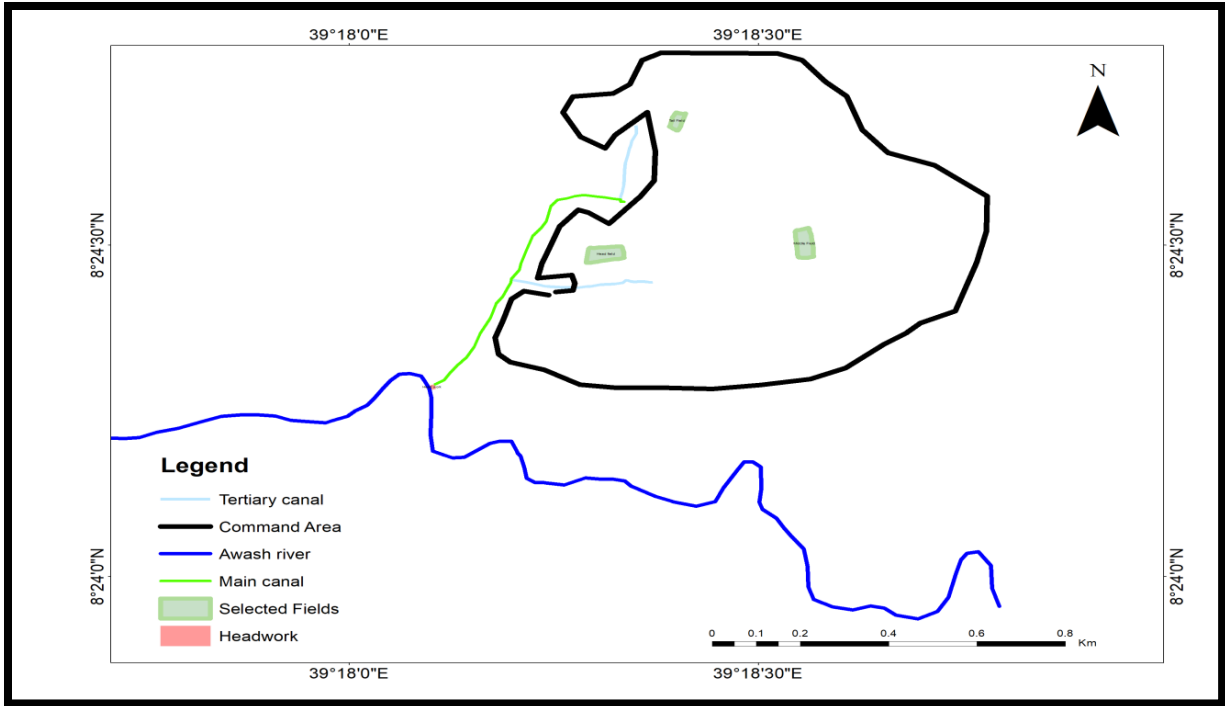


Figure 3. 5: Waqemiya Tiyo irrigation scheme field layouts

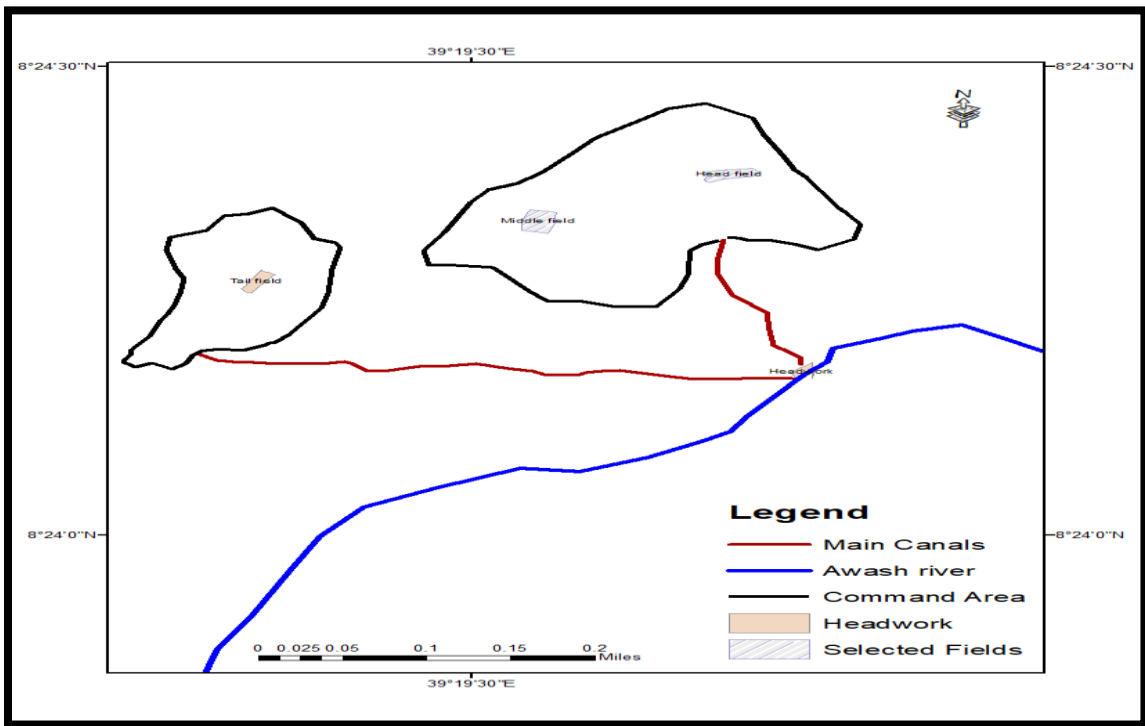


Figure 3. 6: Awash Melkasa irrigation scheme field layouts.

3.5. Data Collection and Analysis

3.5.1. Data collection

Primary and secondary data sources that were collected and used for research in accordance with the study's specific objectives. Thus, the first activity was walking through the study areas in order to get the general information of irrigation practices and command area. The selection of fields was done in considering similarity of crops, dominant crop types under production on both schemes.

3.5.1.2. Primary Data collection

Primary data was collected through field measurements and field observations were practiced for information gathering and analysis.

I. Evaluation of performance for two irrigation schemes:

The following primary data were collected: Frequently, field observations are made to observe and investigate the methods of water application and practices related to water management techniques. The soil data: (bulk density, texture classes, field capacity, permanent wilting point, and soil moisture contents before and two days after irrigation) were analyzed in the soil laboratory, whereas the infiltration rate was measured at the field level for both of irrigation schemes.

Secondary data was collected from different sources. Long-term climatic data for rainfall, relative humidity, wind speed, sunshine hours; maximum and minimum temperatures for 30 years (1990-2020) were collected from National Meteorological Service Agency. Each of this climatic data were computed as it required weather daily or monthly including to generate climatic water balance of study area. The crop information irrigated crops, planting date, total

growth period, developmental phases, crop coefficient, rooting depth, critical depletion level, and yield response factor was taken from published studies by FAO, field observations, and an unofficial field survey. Additionally, data on production and market prices crop yield and local prices of the yield as well as information on area size command area, initially irrigated area, and area irrigated during the study period were gathered from the Kebele, development agent offices (DA), Adama Woreda Agricultural Experts.

II. Evaluation and comparison for two small scale irrigation schemes:

The data collected accordingly to meet the study's specific objective comes from primary sources of data, including: Soil samples were collected by using auger at 30 cm depth intervals from the surface up to the maximum rooting depth of the crop (Tomato) for the determination of bulk density, texture and soil moisture content. Three farmer fields were selected from each scheme at the head, middle, and tail reaches relative to the water source. For each selected fields, the moisture content of the soil was determined by taking soil samples at different depths of soil profiles in selected irrigation fields before and after irrigation by gravimetric estimation. the infiltration rate of the soil was determined by using a double-ring infiltrometer. The maximum infiltration rate was conducted in the farmers' fields to use as input during the CROPWAT 8.0 software estimation for the determination of crop water demand, irrigation water demand, and irrigation scheduling. Three-inch (3-inch) Parshall flumes were used to determine the amount of water applied to the field and the average water depth of irrigation water passing through the flume to the field inlet.

Secondary sources of data, including

Irrigation data: like flow discharges in main and tertiary canals sections; present discharge capacity of the main canal at its head, and depth of irrigation water applied were measured at field level for two irrigation schemes. Data on production market prices crop yield and local prices of the yield as well as information on area size command area, initially irrigated area, and area irrigated during the study period were gathered from Kebele, development agent offices and Adama Woreda Agricultural Experts required for this specific purpose.

3.5.2. Data Analysis

Crop water requirements, irrigation water requirements, and irrigation scheduling were determined using CROPWAT8.0 for data analysis. For each chosen field in both irrigation schemes, technical performance indicators such as conveyance, field application, water storage, overall irrigation efficiency, and distribution uniformity were identified. To analyze field irrigation water management techniques and ongoing operations, internal performance indicators were used. The pertinent data were gathered, measured, and evaluated to determine these internal performance indicators: the depth of irrigation water applied using a Parshall flume; the depth of water stored at the effective root zone from a soil moisture analysis; the total amount of soil water and water that is Readily available and the canal flow discharges area-velocity method using floating objects. However, since farmers used close-end furrows, which prevented runoff loss, recent complementary terms runoff ratio were not analyzed. Subsequently, a calculation was made using the specified performance indicators. Microsoft Excel was used in the data analysis activities for the data collected in the study area.

3.5.2.1. Method for Collecting Soil Samples

The collected samples were used to determine soil texture, bulk density, soil moisture content, field capacity, permanent wilting point and others. The sample field plots were selected based on the availability of water reaching from the conveyance system, at the beginning, middle, and end of each irrigation scheme, soil samples were taken from each chosen fields. Since the soil profile variation in the research sites occurs at intervals of 30 cm, soil samples were taken at (0, 30, 60 and 90) cm of the soil horizon. Because different crops have varying root depths, these soil parameters were established for soil depth inside the cultivated crop effective root zones. Tomato and potato were grown in the chosen fields at the beginning, middle, and end of the Awash Melkasa irrigation scheme. While Onion, Tomato, and cabbage were grown in the chosen fields at the head, middle, and tail ends of the Waqemiya Tiyo irrigation scheme. an interval of 30cm to a depth of 90cm. It is based on the major crops depth that planted on the scheme that the effective root zone of the irrigated vegetable crop is not more than this depth. Here, the major crops that are grown in the area have a depth less equal or the depth taken for the study. The maximum effective root zone of Onion and Tomatoes is 60,90cm, respectively Allen et al., (1998). Finally; for textural analysis eighteen, disturbed composite soil samples of each farmer's field plot. Thus, 54 soil samples head, middle and tail for one scheme totally 108 soil samples were collected for textural analysis in both irrigation schemes. and undisturbed soil for bulk density were collected from three locations along diagonal of the selected fields of head, middle, and tail end using soil auger and core sampler with the depths 0-30cm, 30-60cm, 60-90cm, respectively. Hydrometer method was used for textural analysis and pressure plate apparatus for field capacity and permanent wilting point in laboratory.

Soil Texture and Bulk Density

For textural analysis of the soil, 54 composite samples of disturbed soil were collected from each scheme at three locations along diagonal of the selected fields of each scheme thus, 108 soil samples were sampled from schemes head, middle, and tail. The maximum effective root zone of commend area vegetable Tomato is 90cm Allen et al., (1998).Therefore, using soil auger with the depths(0-30,30-60 and 60-90 cm),Hydrometer method was used for analyzing particle size distribution at Melkasa Agricultural Research Center Laboratory. Based on the percentage of composition each of particle was determined using hydrometer Bouyoucos (1951) and the soil textural class was determined by USAD soil textural triangle method.



Figure 3. 7: Soil texture determination using hydrometer

Using a core sampler, the soil bulk density was determined samples from undisturbed soil. Core size was 2.75cm internal diameter and 4cm height. With volume of 94.985cm^3 at interval of 30cm each the samples were placed with container covered in an oven and dried at 105°C for 24hours.In Melkasa Agricultural Research Center Laboratory. After drying, the soil and container were again weighed and container covered were removed. Then dry-bulk density (Bb)

was computed by dividing the oven dry mass of the soil sample (md) to known volume of core sampler (Vc). Using the following equation, the bulk was determined Brown & Wherrett, (2014).

$$\text{Bulk-density (Bd)} = \frac{md(g)}{vc(cm^3)} \quad (3.1)$$

Where: Bd = bulk-density (g/cm³) md = weight of dry soil (g) VC = volume of soil core (cm³)

Field capacity and permanent wilting point

Soil water content at field capacity and permanent wilting point is important in determination of irrigation, plant water requirement, scheduling assessing and soil suitability for different land uses Grewal et al., (1990). Field capacity and permanent wilting point of the soil were analyzed through pressure plate apparatus in Debre Zeit Agricultural Research Center laboratory. The soil samples were air-dried and then, prepared soil samples were saturated up to all the soil pore spaces filled with water. Then, the prepared soil samples were entered into a pressure plate of 1/3 and 15 bars were applied for field capacity and permanent wilting points respectively. The weight of water retained in a known volume of soil after pressure plates of 1/3 and 15 bars were measured for field capacity and permanent wilting points respectively. Moreover, the weight of the same volume of dry soil was also determined. Finally, the gravimetric soil moisture contents at field capacity and permanent wilting points were determined using equations (3.2) and (3.3) respectively.

$$FC = \frac{\text{Weight of water retained in a known volume of soil}}{\text{Weight of the same volume of dry soil}} * 100 \quad (3.2)$$

$$PWP = \frac{\text{Weight of water retained in a known volume of soil}}{\text{Weight of the same volume of dry soil}} * 100 \quad (3.3)$$

Where: FC= is field capacity at 1/3 bar pressure

PWP=is permanent wilting point at 15 bar pressure

Total available water at the effective root zone was computed by equation 3.4 FAO, (1998)

$$TAW = 1000(FC - PWP) * BD * Dz \quad (3.4)$$

$$RAW = TAW * p \quad (3.5)$$

Where; TAW is total available water (mm); FC is the gravimetric soil moisture content at field capacity (fraction), PWP is the gravimetric soil moisture content at permanent wilting point (fraction), Dz is the effective root zone of a crop (m), Bd is bulk density (gm/cm^3), RAW is readily available water (mm); p is critical depletion level for each crop (fraction).

Measurements of moisture content of the soil

The moisture status was measured to determine how much water depleted below the field capacity before irrigation and how much water applied to the root zone after irrigation. Soil moisture content measurement is necessary to know the moisture holding capacity of the soil found in command area for different parametric analysis, which has relationship with soil. In this study, Soil samples were taken one day before and two days after irrigation. Using sampling auger soil samples at different depths up to 90cm root depth from farm plots by 30cm interval in each both schemes sample will take from head, middle, tail collected and weighted using analytical balance and placed in an oven heated to 105°C for 24 hrs with the container cover removed. After drying the soil and container is again weighted and weight of water is determined and the dry fraction of each sample is calculated using equation (FAO, 1989).

$$\theta_w = \frac{W_w - W_d}{W_d} * 100 \quad (3.6)$$

Where: θ_w - soil water content on a dry weight basis (%)

W_w - is wet weight of the soil (g)

W_d - is dry weight of the soil (g)

Then the moisture contents of the soils collected from the selected fields at different depths were determined, the volumetric water content was calculated from the gravimetric water content using the following expression.

$$\theta V = \theta W \times Bd \quad (3.7)$$

Where: Bd: - Soil bulk density (g/cm^3)

θV :- volumetric moisture content



Figure 3. 8: Soil moisture determination using oven dry method.

Soil infiltration rate measurement

The ability of the soil to permit water passage into and through the soil profile is referred to as soil infiltration Johnson(1963).Concluded that the major basic factor that impacts the infiltration rate in crop fields is the soil texture. For all of the specific fields of the two irrigation schemes loam soil is the dominant soil texture, as previously noted. As a result, changes in soil texture were mainly used to determine the number of infiltration test points. Therefore, one infiltration test was carried out in each field of study of the two irrigation schemes in this study. In this investigation, a double ring Infiltrometer was used to calculate the soil's infiltration rate. The inner and outer rings, which are made up of two metal cylinder rings that are concentric, have

respective diameters of 30 cm and 60 cm. The hammer pushed these rings 15 centimeters into the ground. Water was added to the soil with certain interval of time. A stop watch was also used to record time the cumulative depth of infiltration and the time elapsed was recorded carefully. Measurements were taken in the internal ring, but the purpose of the external ring was protecting the lateral movement of the water through the soil. The first infiltration rate, which occurs immediately after applying water, is very quick. The water from the soil surface infiltrates more slowly at first, eventually reaching a stable rate that was referred to as the "basic infiltration rate," as more water replaces the air in the pores. Measurements were taken in a single installation of the double ring Infiltrimeter for three hours; it is an input parameter for CROPWAT8.0 for the computation of total crop water and irrigation requirements.



Figure 3. 9: Infiltration rate test at field level

3.5.3. Internal Performance Indicators

3.5.3.1. Application Efficiency (Ea)

The application efficiency was computed as the ratio of moisture stored in the soil profile due to irrigation to the total irrigation water applied to the field. In this study, the amount of irrigation water applied to the field was determined using three-inch Parshall flume. The depth of water which is stored in the root zone of the soil was determined by collecting soil Samples at different depths (0-30, 30-60 and 60-90 cm) two days after irrigation. Three row furrows were selected along each field (one row from the center and two rows from opposite sides) and three test points were identified starting from the beginning to the end of each row at regular interval. The total soil samples were 486 before and after two days of irrigation. Finally, the moisture content stored in the root zone was determined by a gravimetric method using equation (3.9) total depth of irrigation water farmers applied to their fields was determined using the following formula (3.8). Application efficiency was computed as follows (Michael, 2008):

$$W_f (\text{mm}) = (T*Q)/A \quad (3.8)$$

Where: W_f is depth of water used in the field (mm)

T is time elapsed during irrigation (se),

Q is water discharge on field (m^3/se), and

A is area of the sample field (m^2).

Formula used to calculate the typical depth of water stored in the root zone:

$$W_s \text{ (mm)} = \sum_{i=1}^n \left(\frac{\theta_{AI} - \theta_{BI}}{100} \right) * i * D_i \quad (3.9)$$

Where: θ_{AI} and θ_{BI} are the moisture content of the i th soil compartments after and before irrigation on an oven dry volume basis (%), respectively; D_i is the thickness of i th soil compartments (mm), and n is the number of compartments in the root zone.

$$E_a = \frac{W_s}{W_f} * 100 \quad (3.10)$$

Where: - E_a : - application efficiency

W_s : - average depth water stored in the root zone of the plant

W_f : - average water delivered to the field (water depth applied to the field).



Figure 3. 10: Measurement of Field Applied Irrigation Water Using Parshall Flume

3.5.3.2. Storage Efficiency (E_s)

To determine the water stored in the soil root zone of each field, soil samples were collected from a different location within the field at a depth of the 0-30, 30-60 and 60-90 cm before and after each irrigation event. The moisture content was determined using the gravimetric method.

Michael, (2008): Storage efficiency is obtained by the relationship given below.

$$Es = \frac{Ws}{Wn} * 100 \quad (3.11)$$

Where: - Es: - storage efficiency (%)

Ws: - water stored in the root zone during irrigation (mm)

Wn: - water needed in the root zone prior to irrigation (mm)

The water needed in the root zone prior to irrigation was computed using the following Equation (Michael, 2008).

$$Wn = \sum_{i=1}^n \left(\frac{Mfci - Mbi}{100} \right) * Ai * Di \quad (3.12)$$

Where: - Di: - net amount of water to be applied during irrigation (mm)

Mfci: - field capacity moisture content in the i layer of the soil (%)

Mbi: - moisture content before irrigation in the i the layer of soil (%)

Ai: - bulk density of the soil in the i the layer

Di: - depth of the soil layer within the root zone cm, and

n: - number of soil layers in the root zone D

3.5.3.3. Conveyance Efficiency (Ec)

Canal discharge measurement

To determine canal flow discharge the flow at main and tertiary canals at hundred meter interval recorded using area velocity method. Lined main canal and unlined main canal measured at Waqemiya Tiyo and Awash Melkasa irrigation schemes respectively. The velocity was measured by floating methods; the discharges were calculated from the canals cross-sectional area, and the measured velocities. Considering that it is more preferable in circumstances where other techniques are impracticable and since it is uncomplicated and economical Heiner & Vermeyen,

(2013) Thus, Floating material was put on the upper part (inlet) of the canal section, the time it took to reach the known distance section of the same canal was recorded in several replications, and the average time used to calculate the velocity of the flow. The cross-sectional area of the canal was determined by measuring the average depth and width of the same canal section. The second measurement was also taken at a fixed distance above the downstream end of the main and tertiary canal. The same procedure was followed to estimate the discharge at the second point (outlet) so that the amount of conveyance loss was known, and the conveyance efficiency was determined.

Thus, to determine the mean flow velocity, the flow velocity of the water at the surface, V_s was first determined. The surface velocity was determined by measuring the time it takes for a floating object was recorded using stopwatch along the canal. The floating object used were empty bottle was placed in the center of a canal and the time measurement was repeated four times to avoid mistakes. The canal used for measurement should be straight and uniform, in order to avoid changes in the velocity and in the area of the cross-section, because any such variation reduces the accuracy of the velocity estimation. The velocity of the floating object on the surface of the water was greater than the mean velocity of the stream, in order to correct the effect of streams bottom there is a correction factor which is 0.85 based on the bed roughness it ranges from 0.8 to 0.9 Liggett (2001). To calculate velocity of the float, V_s the selected length, L was divided by the travel time, t

$$V_s = \frac{L}{t} \quad (3.13)$$

$$V_{\text{mean}} = V_s * k \quad (3.14)$$

Where, V_s : velocity of the float (m/s) V_{mean} : mean flow velocity (m/s) L the distance in meters(m) between selected points; T the travel time in seconds(s) between selected point; k

correction coefficient For a selected straight and uniform section of the canal, the area of the wetted cross-section was determined. Waqemiya Tiyo irrigation canal's main canal has a rectangular cross section; hence cross sectional area was calculated using measurements of the water's width and depth.

$$A = w * h \quad (3.15)$$

Where: A: area of wetted cross-section (m²); w surface water width of the canal (m); h water depth of the canal (m).

Floating methods were used to determine the flow velocity through the main and tertiary canals. Floating material was placed upstream of the measuring distance after the canal's dimension was measured with a tape meter. For the purpose of calculating flow velocity, the time it takes to cross specific distance was recorded. Finally, using the continuity equation, the flow's discharge was determined.

$$Q = A_w * V_{\text{mean}} \quad (3.16)$$

Where: V_{mean} , is mean flow velocity (m/s),

A_w is canal wetted cross-section area (m²) and

Q is flowing discharges (m³/s).

The following equation was used to calculate the canal conveyance losses from inflow-outflow discharges measured in canal sections by equation (3.17) (Mohammadi et.al, 2019).

$$QL = \frac{Q_{in} - Q_{out}}{L} \quad (3.17)$$

Where QL is water loss rates (l/s/m), Q_o is outflow at the outlet of canal sections (l/s), Q_i is inflow at the inlet of canal sections (l/s) and L is canal length between inlet and outlet (m).

Conveyance efficiency is measures the efficiency of the canal system to delivery water from the source to the target place and shows the amount of water loss over a given canal length. To estimate the conveyance efficiency and conveyance loss in the canal systems, the inflow and outflow discharges were used. The conveyance efficiency was computed as the ratio of outflow to inflow discharges by equation (3.18).

$$E_c = \frac{Q_{out}}{Q_{in}} * 100 \quad (3.18)$$

Where: E_c is conveyance efficiency .The conveyance efficiency of a canal depends on the types of canals, construction materials, soil type, proper construction and maintenance, and amounts of flow rate FAO, (1989).Finally, conveyance efficiency of the scheme (%) computed by the following formula:

$$E_c = (E_{c,mc} * E_{c,Tc})/100 \quad (3.19)$$

Where: mc and Tc are conveyance efficiencies at the main and tertiary canals, respectively.

3.5.3.4. Overall Irrigation Efficiency

It describes the efficiency of the entire physical system and irrigation system that convey irrigation water from the sources to the field crops, but excludes the efficiency of the root zone storage system. The overall irrigation efficiency was computed by equation 3.19 Rai *et al.*, (2017).

$$E = (E_c * E_a)/100 \quad (3.20)$$

Where: E is the overall irrigation efficiency (%) E_c is conveyance efficiency and E_a is the field application efficiency.

3.5.3.5. Distribution Uniformity (Du)

Distribution uniformity is used to measure the variation or non-uniformity of water applied to the entire field. The moisture content collected in various furrow locations was calculated using a small quarter, and the results were then arranged in ascending order. Finally, the uniformity of distribution was determined using the equation Walker, (2003). To determine the amount of water stored in the root zone, each farm was divided into three parts at the head, middle, and tail of the field. Then in each divided part, three furrows were selected from each farmer's field, and furrow was also divided into three parts. Finally, soil samples were taken from nine points carefully chosen locations before and after two days each irrigation event, at intervals ranging from 30 to 90 cm. then after soil moisture contents of the soil samples determined gravimetrically, at the selected points, the depth of stored water at particular soil layer (X (0-30) or X (30-60)) was calculated using the equation:

$$X = \left(\frac{M_{ai} - M_{bi}}{100} \right) * A_i * D_i \quad (3.21)$$

Where: M_{ai} = moisture content of the i^{th} layer of the soil after irrigation weight basis, %

M_{bi} = moisture content of the i^{th} layer of soil before irrigation weight basis, %

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

D_i = soil depth of i^{th} layer

The total depth of water stored at each point (X1 to X9) was determined, by sum up the Values of X1(0-30), X1(30-60) and X1(60-90) of that specific point.

That is:

$$X1 = X1(0-30) + X1(30-60) + X1(60-90) \quad (3.22a)$$

To

$$X9 = X9(0-30) + X9(30-60) + X9(60-90) \quad (3.22b)$$

Then finally, the distribution uniformity was determined using equation 3.23.

$$Du = \frac{XLq}{Xm} * 100 \quad (3.23)$$

DU: - Water distribution uniformity (%)

X_{Lq} : - the mean of lower-quarter depth of water stored and

X_m : - the mean depth of all water stored

3.5.4. External Performance Indicators

For the performance evaluation of the schemes, nine external indicators were used as illustrated by International Water Management Institute Molden et al., (1998) three groups of the selected external performance indicators were evaluated for two irrigation schemes. These three groups of external performance indicators were irrigated agriculture performance indicators (output per unit irrigated area, output per unit command area, output per unit irrigation supply and output per unit water consumed), water delivery performance indicators (relative water supply, relative irrigation supply and water delivery capacity) and physical performance indicators (sustainability of irrigated area and irrigation ratio).

3.5.4.1. Irrigated Agricultural Output Performance Indicators

To determine the external indicators of the scheme like output per cropped area, output per unit command area, and output per unit water consumed production such data crop production, irrigable-cropped area and command area were collected from Adama District Agricultural Office. Each crop production (US\$/ha), Total production (US\$/ha) for the year 2021/2022 was calculated by using local farm gate price and yield production of Irrigation Scheme. To compute agricultural output indicators, the following equations were used (Molden et al., 1998).

$$1. \text{Output per unit irrigated area } \left(\frac{\text{US\$}}{\text{ha}} \right) = \frac{\text{Production}}{\text{irrigated cropped area}} \quad (3.24)$$

$$2. \text{Output per unit command area } \left(\frac{\text{US\$}}{\text{ha}} \right) = \frac{\text{Production}}{\text{Command area}} \quad (3.25)$$

$$3. \text{Output per unit irrigation supply } \left(\frac{\text{US\$}}{\text{m}^3} \right) = \frac{\text{Production}}{\text{Diverted irrigation supply}} \quad (3.26)$$

$$4. \text{Output per unit water consumed } \left(\frac{\text{US\$}}{\text{m}^3} \right) = \frac{\text{Production}}{\text{The volume of water consumed by ET}} \quad (3.27)$$

Where Production is the output of the irrigated area measured at the local market; Irrigated area is the sum of the areas irrigated during the period of analysis; Command area is the designed area; Diverted irrigation supply is the volume of irrigation water diverted throughout the crop growing period and Volume of water consumed by ET is the actual evapotranspiration of the whole cultivated crops.

3.5.4.2. Water Delivery performance Indicators

Relevant data, like the total net irrigation water applied, is used to evaluate water delivery performance indicators (seasonal irrigation water applied); total net water applied (the sum of seasonal irrigation water applied and effective rainfall); total net crop water requirement

(seasonal crop water requirement); total net irrigation water requirement (seasonal crop water demand less effective rainfall); discharge capacity of the main canal at the system head and peak irrigation flow demands were determined for each irrigation scheme. Total irrigation water applied for a season was estimated from the measured depths of irrigation water applied. The depth of irrigation water applied per interval for the known plot of the irrigated area was measured as described in section 3.5.3. The seasonal depths of irrigation water applied were equal to the product of the depth of irrigation water applied per interval and the number of irrigation (Garg, 2006). The total irrigation water and effective rainfall were used to calculate the total net water applied.

3.5.4.3. Determination of Crop Water and Irrigation Water Requirement

Using the CROPWAT 8.0 model (FAO, 1977), the crop water, irrigation water requirements, and irrigation scheduling of the major irrigated crops in the study area were analyzed. The model needs the climatic data, crop and soil data for the determination of crop water and irrigation water requirements. The model uses the FAO (1992) Penman Monteith equation for Calculating reference evapotranspiration. The crop water requirement can be calculated as follows:

Total net crop water requirement was computed from the crop water requirement of each cultivated crop by equation (3.28). While the total net irrigation water requirement was computed from the irrigation requirements of each cultivated crop by equation (3.29) then, using the following equation the whole seasonal crop water demand for each irrigation scheme's irrigated area was computed. (3.30). But, the volume of seasonal irrigation water demand in the whole irrigated area was computed by equation (3.31).

$$CWR_{total} = \sum_{i=1}^7 \frac{CWR_i * \text{Area of crop}(i)}{\text{Total Area}} \quad (3.28)$$

$$IR_{total} = \sum_{i=1}^7 \frac{IR_i * \text{Area of crop}(i)}{\text{Total Area}} \quad (3.29)$$

$$CWR_v = 10 * CWR_{total} * A_{total} \quad (3.30)$$

$$IR_v = 10 * IR_{total} * A_{total} \quad (3.31)$$

Where, $CWR_{(i)}$ and $IR_{(i)}$ are the depth of crop and irrigation requirements for each crop (mm) respectively, CWR_{total} is the depth of seasonal crop water demand for whole scheme irrigated area (mm), IR_{total} is the depth of seasonal irrigation water demand for whole scheme irrigated area (mm); CWR_v is the volume of seasonal crop water demand (m^3); IR_v is the volume of seasonal irrigation water demand (m^3) and A_{total} is total irrigated area (ha). Then, the peak scheme irrigation water demand for the whole scheme's irrigated area was computed using equation (3.31).

$$GIR_{max} = \frac{IRn_{max}}{E_s} \quad (3.32)$$

$$q \left(\frac{l/s}{ha} \right) = \frac{(0.001 * GIR_{max} * 10,000 * 1000)}{B_{max} * 24 * 60 * 60} \quad (3.33)$$

Where B_{max} is the maximum total growing period; GIR_{max} is the maximum gross irrigation requirement IRn_{max} is the maximum net irrigation requirement and E_s is schemes efficiency.

3.5.4.4. Water Supply Indicators

Relative irrigation and relative water supply for both irrigation schemes evaluated for four consecutive months from December to April when the months are very sensitive for the additional water to fill moisture deficit of the soil. Irrigation supply is the volume of irrigation water delivered from the river source, which is the flow of those four consecutive months measured at the headworks of both schemes.

Relative Water Supply

According to Raghuwanshi and Wallender (1998), the relative water supply was determined as the ratio of total water supply to total crop water demand.

$$RWS = \frac{\text{Total water supply (m}^3\text{)}}{\text{total crop water demand (m}^3\text{)}} \quad (3.34)$$

Relative Irrigation Supply

The relative irrigation supply was determined as the ratio of total irrigation water supply to the total irrigation water demand. Using equation 3.35 (Perry, 1996).

$$RIS = \frac{\text{Total Irrigation supply (m}^3\text{)}}{\text{Total irrigation water demand (m}^3\text{)}} \quad (3.35)$$

3.5.4.5. Water Delivery Capacity (WDC)

The main canal capacity computed from the canal structure cross-section at the diversion intake by measuring the area, velocity and freeboard considered. The peak monthly demand computed by CROPWAT 8.0 models. Thus, the water delivery capacity at the head of the main canal was computed as the ratio of the present canal capacity at the system head to peak consumptive demand by equation 3.36 Molden *et al.*, (1998). It evaluates whether or not the current capacity of the irrigation scheme satisfied the peak demand of whole irrigated crops.

$$WDC = \frac{\text{Canal capacity to deliver water at system head}}{\text{Peak consumptive demand}} \quad (3.36)$$

3.5.4.6. Physical Performance Indicators

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

$$\text{Irrigation Ratio} = \frac{\text{Irrigated cropped area}}{\text{Command area}} \quad (3.37)$$

Where: -Irrigated cropped area (ha) is the portion of the actual irrigated land in any given irrigation season, Command area (ha) is the potential scheme command area.

Sustainability of irrigated area is the ratio of irrigable cropped area to initially irrigated area. This important indicator mainly used to observe the status of the irrigation systems either contracted or expanded.

$$\text{Sustainability of Irrigated Area} = \frac{\text{Irrigated cropped area}}{\text{Initially Irrigated area}} \quad (3.38)$$

Where: irrigated cropped area - area that is currently irrigated ha; initially irrigated area: the designed irrigable area ha; Scheduling and Estimation of Irrigation Duration.

3.5.6. Comparison between Two Irrigation Schemes

In this study, the comparison between two irrigation schemes was made based on estimated values of the external performance indicators (such as relative water supply, relative irrigation supply, water delivery capacity, output per unit irrigated area, output per unit command area, output per unit irrigation supply, output per unit water consumed, sustainability of irrigated area and irrigation ratio. and the elements of internal indicators were used to have additional information about the schemes under comparison.

4. RESULTS AND DISCUSSION

4.1. Physical property of soil

Based on laboratory analysis of particle size distribution, the soil physical property analyses are presented in (Table 4.1 and 4.2) and loam is dominant soil textural class at two irrigation schemes. According to the USDA SCS soil textural triangle method the result indicates that soils of the schemes are nearly the same textural classes at both SSI schemes under the study.

Table 4. 1: Selected Soil Physical Characteristics of Waqemiya Tiyo Irrigation Scheme

Field position	Soil depth (cm)	Particle size distribution (%)			Textural Class	Bulk density (g/cm ³)	FC (%vol)	PWP (%vol)	TAW (mm/root depth)
		Clay	Silt	sand					
Head	0-30	27	32	41	loam	1.29	39.6	22.6	50.9
	30-60	28	30	42	Clay loam	1.27	39.4	22.9	49.4
	60-90	27	30	43	loam	1.30	39.6	22.8	50.2
Total						1.28	39.5	22.8	150.5
Middle	0-30	22	12	40	loam	1.27	36.5	18.8	53.2
	30-60	24	17	39	loam	1.31	39.1	20.8	55.0
	60-90	32	13	41	Clay loam	1.29	42.6	26.1	49.4
Total						1.29	39.4	21.9	157.6
Tail	0-30	21	30	49	loam	1.31	34.8	18.7	48.2
	30-60	23	28	49	loam	1.33	36.7	20.5	48.6
	60-90	29	22	40	Clay loam	1.35	43.0	25.0	53.7
Total						1.33	38.2	21.4	150.6

As indicated in table (4.1 and 4.2) Average bulk density at head, middle and tail of canal reaches were 1.28, 1.29, and 1.33 and 1.30, 1.28, 1.30 g/cm³ in Waqemiya Tiyo and Awash Melkasa irrigation schemes respectively. The bulk density of the soil in both irrigation schemes indicated that as the depth goes down, the bulk density increases, which indicates that the soil has compacted and the depth goes down the bulk density increased, which implies the soil compactness increased as goes down to deep. According to Jones et al.,(2003). Bulk density rating classification, the bulk density values of the soils were low if bulk density is less than 1.4g/cm³, medium if bulk density is between 1.4-1.8 g/cm³ and high if bulk density is greater than 1.8g/cm³. Therefore, the result of the average bulk density of the soil at study area becomes below 1.4gm/cm³ which is indicates that there was no compaction that could limit infiltration of water into and through the soil root penetration and it's at normal range of organic matter content in order to get better plant growth. Soil physical analysis of Waqemiya Tiyo Irrigation Scheme showed that average moisture content of volume base at field capacity (FC) was 39.5, 39.4 and 38.2% vol at the head, middle and tail reach, respectively. Whereas, at Awash Melkasa irrigation scheme 43.3, 36.7 and 40.3% vol were recorded at the head, middle and tail reach, respectively (Table 4.2). On the other hand, the volume base moisture content at the permanent wilting point (PWP) at Waqemiya Tiyo was 22.8, 21.9 and 21.4 at the head, middle and tail reach, respectively. At Awash Melkasa 24.5, 19.2 and 21.9 % vol were observed at the head; middle and tail reach of the scheme, respectively The volumetric total available water content (TAW) at 90cm of soil depth for both irrigation scheme were ranged from (160.8 to 183.2 mm/m) and (165.5 to 197.5mm/m) in Waqemiya Tiyo and Awash Melkasa in each of selected field Irrigation Schemes, respectively.

Table 4. 2: Selected Soil Physical Characteristics of Awash Melkasa irrigation scheme

Field position	Soil depth (cm)	Particle size distribution (%)			Textural Class	Bulk density (g/cm ³)	FC (%vol)	PWP (%vol)	TAW (mm/root depth)
		Clay	Silt	Sand					
Head	0-30	35	38	27	Loam	1.27	40.2	22.1	54.3
	30-60	28	31	25	Clay loam	1.31	44.3	23.6	62.1
	60-90	33	30	39	Clay loam	1.34	45.3	27.9	52.2
Total						1.30	43.3	24.5	168.6
Middle	0-30	25	28	43	loam	1.26	37.4	20.8	49.6
	30-60	22	30	45	loam	1.28	35.6	18.9	50.2
	60-90	20	16	39	loam	1.30	36.7	17.8	56.6
Total						1.28	36.7	19.2	156.4
Tail	0-30	22	32	34	loam	1.30	39.0	19.2	59.2
	30-60	28	27	36	Clay loam	1.29	41.3	23.3	54.0
	60-90	27	20	42	loam	1.32	40.6	23.3	51.9
Total						1.30	40.3	21.9	165.2

The average total available water obtained in this study was (168.7 and 160.7mm/m) for Waqemiya Tiyo and Awash Melkasa irrigation schemes respectively. TAWS of both schemes are with the range FAO (1985) 120-200mm/m Recommendation for the for particular soil type. The soil physical analysis result revealed that soil at Waqemiya Tiyo Irrigation Scheme had good water holding capacity than the loam dominant soil type of Awash Melkasa Irrigation scheme. This is an important condition for Waqemiya Tiyo Irrigation Scheme that, longer irrigation interval were practiced in an area where there is high competition for irrigation water.

4.2. Soil Infiltration Rate

At the beginning of the experiments, infiltration rates were at highest values; however, as supply water continues and the uppermost soils get saturated, the infiltration rate gradually declines and eventually stabilizes at a rate that is almost constant. Basic infiltration rates were measured in the field at 9 and 10 mm/hr at Waqemiya Tiyo and Awash Melkasa irrigation schemes respectively. As explained above, the results of the soil laboratory showed that loam is the dominant type of soil texture in both the study area.

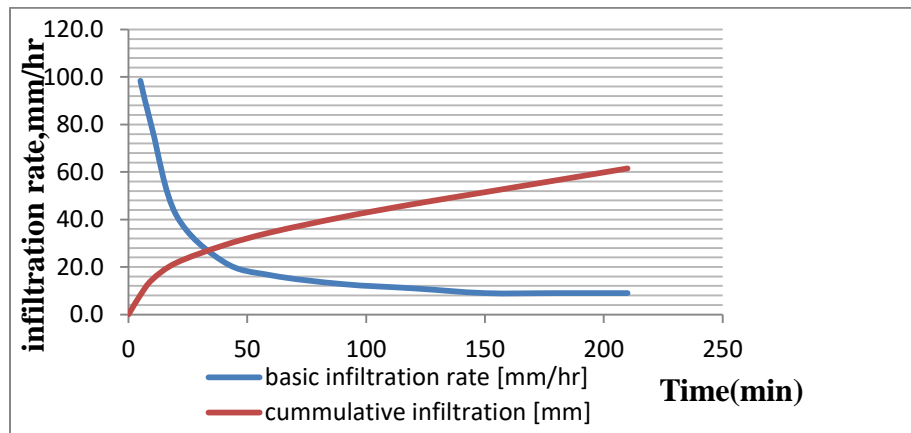


Figure 4. 1: cumulative and basic infiltration rate for Waqemiya Tiyo scheme

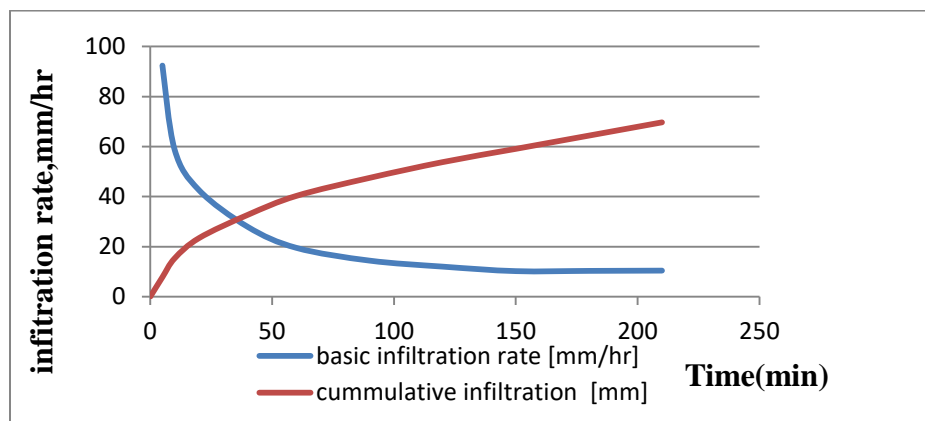


Figure 4. 2: cumulative and basic infiltration rate for Awash Melkasa scheme

Recommended values the result obtained for basic infiltration rates were used for evaluation of farmer application rate of the irrigation water and also used as input data for CROPWAT 8.0 model to determine the irrigation scheduling and crop water requirement determination.

4.2.1 Irrigated Crop Coverage

The types of crops grown by the beneficiaries of the irrigation scheme are listed in (Table 4.3) in hectare and percentage terms. Waqemiya Tiyo and Awash Melkasa irrigation schemes cover the largest percentages of Tomato and Onion 55 and 47%, respectively. In two irrigation schemes Tobacco, Pepper, Potato and Cabbage cover 1, 3,7,10 and 6, 3, 11 and 5% out of the total area coverage of the scheme, respectively. The study found that Waqemiya Tiyo had better in terms of crop productivity than the Awash Melkasa irrigation scheme. Because more than half of the land under the Waqemiya Tiyo irrigation scheme is planted, it has a higher irrigation ratio than the Awash Melkasa Irrigation scheme.

Table 4. 3: Two Irrigation Schemes' Major Crops and Area Coverage

Irrigated crop type	Waqemiya Tiyo Scheme		Awash Melkasa Scheme	
	Area coverage (ha)	Percentage of the total area (%)	Area coverage (ha)	Percentage of the total area (%)
Tomato	125.0	55	80.7	47
Onion	55.3	24	45.6	27
Potato	15	7	18.7	11
Cabbage	21.7	10	8.9	5
Tobacco	3.0	1	10.4	6
Pepper	7.5	3	5.7	3
Total	227.5	100	170	100

4.3. Crop Water Demand and Irrigation Requirement

Each irrigated crop's needs for Crop water requirements and irrigation requirements were calculated using the CROPWAT 8.0 program based on the crop type, planting date, and harvesting date of each crop. The entire year is considered one season. According to CROPWAT 8.0 model calculations, Tomato had water requirements of 580375 and 246619m³ per season for the Waqemiya Tiyo and Awash Melkasa irrigation schemes, respectively While onion had Requirements of 221089 and 217010m³ per season. The result is as shown below (Table 4.4): A similar trend was also seen in Irrigation Requirements. Due to their shorter growth cycle than the others, Tobacco had the lowest crop water needs. The lower irrigation water requirements were obtained from Pepper and Tobacco at the Waqemiya Tiyo and Awash Melkasa irrigation schemes, respectively.

Table 4. 4: Summary of CWR and IR results for each crop types

Irrigated Crop type	Growing Season (Day)	Waqemiya Tiyo Irrigation Scheme		Awash Melkasa Irrigation Scheme	
		CWR/Season (m ³)	IWR/Season (m ³)	CWR/Season (m ³)	IWR/Season (m ³)
Tomato	115	580375	561875	246619	233545.8
Onion	110	221089	213292.1	217010	209942.4
Potato	115	66765	64035	82617	79849.0
Cabbage	120	45630	43418.7	44232	42276.45
Pepper	120	30975	29400	23335	22148.0
Tobacco	100	11169	10899	38831	37892.2

4.4. Scheme Status with Selected Internal Performance Indicators

I. Conveyance efficiency and losses from the main canal: The data from Table (4.5 and 4.6) shows that the conveyance efficiency of the main canal of the Waqemiya Tiyo and Awash Melkasa irrigation schemes has decreased from the source to the middle until the user tail. At the tail or before branching into the third canal, the effectiveness of the main canal is 90, 81, and 68%. For the Waqemiya Tiyo irrigation scheme. And 83.3, 70.8, and 62.2% Main canal-1 and 86.9, 74.3 and 59.5% Main canal-2 at the head, middle, and tail, respectively, for Awash Melkasa irrigation scheme. The results show that Waqemiya Tiyo irrigation scheme has a better conveying system than the Awash Melkasa irrigation scheme (See Table 4.5 and 4.6).

Table 4. 5: Canal Conveyance Efficiency and Loss for Waqemiya Tiyo Irrigation Scheme

Main Canal section	Waqemiya Tiyo Irrigation Scheme	
	Conveyance efficiency(E_c,mc) (%)	Conveyance losses(E_c,ml) l/s/100m
Head	94	0.8
Middle	89.7	1.0
Tail	81.9	1.2
Average	88.53	1.0

(E_c, mc):-main canal conveyance efficiency & (E_c, ml):- main canal conveyance losses

Table 4. 6: Canal Conveyance Efficiency and Loss for Awash Melkasa Irrigation Scheme

Main Canal section	Awash Melkasa irrigation scheme				
	Main canal -1		Main canal -2		
	Conveyance efficiency(E_c,mc) (%)	conveyance losses(E_c,ml) l/s/100m		Conveyance efficiency (E_c,mc) (%)	conveyance losses(E_c,ml) l/s/100m
Head	88.6	1.1	Head	86.9	1.0
Middle	80.1	1.3	Middle	78.5	1.1
Tail	76.5	2.2	Tail	72.4	2.4
Average	81.73	1.9	Average	79.3	1.8

Average water conveyance losses per 100m in the Waqemiya Tiyo irrigation schemes were 1.0l/s/ whereas; they were 1.9l/s/ and 1.8l/s/ at Main canal-1 and Main canal-2 respectively, in the Awash Melkasa irrigation schemes. The Awash Melkasa irrigation scheme had the highest average conveyance loss of 1.9%, which was higher than the 1.0% loss of major canals in the Waqemiya Tiyo irrigation scheme. Since the irrigation water from Awash Melkasa has sustained significantly more losses than the irrigation water from Waqemiya Tiyo that comes from the main canal. The reasons for the high losses in the Awash Melkasa scheme are that 800 meters from the top of the irrigation scheme are made of unlined canals, and the rest of the ditches are filled with soil, weeds, and silt see Figure 3.3.

In Awash Melkasa irrigation scheme, the average water conveyance efficiency was 72.1, 73.5% at main canal-1 and 2 respectively, whereas in Waqemiya Tiyo the results were 80% (Table 4.5). FAO (2001) recommended that the conveyance efficiency for lined canals of any length is 95%. For earthen canals with clay soil could be 80%, 85%, and 90% for canal lengths of >2000m, 200-2000m, and <200m respectively. The current finding indicates that the average conveyance efficiency of the main canal for the Waqemiya Tiyo irrigation scheme is good. However, Awash Melkasa is below the recommended value as shown in Table (4.6). As a result, the conveyance efficiency of the Awash Melkasa irrigation scheme was poor. The main reason might be evaporation losses, malfunctioning of high sedimentation, illegal water turnouts in main and Tertiary canals, water stagnation, grass covers of the canals' waterway, and canal size widening. As a result, the Waqemiya Tiyo irrigation scheme at the main canal performed better than Awash Melkasa irrigation scheme.

II. Water conveyance efficiency and losses for tertiary canals: Based on equations 3.19 and 3.20, they are used to calculate estimates of the effectiveness of water conveyance and the loss of tertiary canals. The study found that, at the head, middle, and tail reaches of the Awash Melkasa irrigation scheme, respectively. The conveyance efficiency of the tertiary canal was 62.9, 54.4, 50.2 and 60.4, 53.9, 46.9 % at main-1 and 2 canal respectively. While on, Waqemiya Tiyo conveyance efficiency was 65.4, 52.3 and 48.6% for the head, middle, and tail ends and access to the system, respectively. (Table 4.7 and Table 4.8). Waqemiya Tiyo Irrigation system on the tertiary canal transports irrigation water more effectively than the Awash Melkasa irrigation system. A similar finding was reported by Alebachew and Singh (2018), in which the water distribution uniformity of the tertiary canal was 56%.

Table 4. 7: Conveyance Efficiency of tertiary canal for Waqemiya Tiyo Irrigation Scheme

Tertiary canal section	Waqemiya Tiyo Irrigation Scheme	
	Conveyance efficiency(E_c, T_c) (%)	conveyance losses(E_c, T_l) l/s/m
Head	65.4	1.7
Middle	52.3	2.9
Tail	48.6	3.3
Average	55.4	2.6

Table 4. 8: Conveyance Efficiency of the tertiary canal for Awash Melkasa Irrigation Scheme

Tertiary Canal section	Awash Melkasa irrigation scheme				
	Main canal -1		Main canal -2		
	Conveyance efficiency(E_c, T_c) (%)	conveyance loss(E_c, T_l) l/s/m		Conveyance efficiency(E_c, T_c) (%)	conveyance loss(E_c, T_l) l/s/m
Head	72.4	1.6	Head	64.7	2.2
Middle	52.3	2.8	Middle	54.5	3.0
Tail	48.6	3.2	Tail	46.9	3.4
Average	57.8	2.5	Average	55.4	2.9

III. Overall conveyance efficiency and losses: The study found that the overall conveyance efficiencies of the canals for Waqemiya Tiyo and Awash Melkasa irrigation schemes were 49% and 45.6%, respectively. (Table 4.9 and 4.10). The reason might be losses of water in conveyance systems. Compared to Awash Melkasa irrigation scheme Waqemiya Tiyo irrigation scheme has higher conveyance efficiency, according to the result.

Table 4. 9: Conveyance efficiency and losses of Waqemiya Tiyo irrigation schemes

Canal section	Waqemiya Tiyo Irrigation Scheme		
	Conveyance efficiency (Ec, Tc) (%)	Conveyance losses (Ec, Tl) l/s/100m	Conveyance losses (Ec, Tl) l/s/m
Main canal	88.5	1.0	
Tertiary canal	55.4		2.6
Ec ₀	49.00		

Table 4. 10: Conveyance efficiency and losses of Awash Melkasa irrigation schemes

Canal section	Awash Melkasa irrigation scheme	
	Conveyance efficiency (Ec,Tc) (%)	conveyance loss(Ec,Tl) l/s/m
Main canal-1	81.7	1.9
Main canal-2	79.3	1.8
Canal section	Conveyance efficiency (Ec,Tc) (%)	Conveyance Losses l/s/m
Tertiary Main canal-1	57.8	2.5
Tertiary Main canal-2	55.4	2.9
Ec ₀	45.58	

*Ec, Tc:-tertiary canal conveyance efficiency and * Ec, Tc:-tertiary canal conveyance losses

The major causes of high water loss are sedimentation, weeds, cracks, and more parts constructed by earth canals. Water supply equity across all systems is impacted by this unequal distribution; in particular, tail users did not receive their fair share within the required timeframe.

4.4.1. Application Efficiency (Ea)

Water application efficiency provides a general indication of how well an irrigation system. The results of application efficiency obtained using the method described in equation (3.10) for head, middle and tail reaches. The Application efficiency of selected fields at the Waqemiya Tiyo irrigation scheme was found to vary from 52.7% to 68.6% with an average of 56.2% but the same parameter for selected fields at the Awash Melkasa irrigation scheme vary from 51.7% to 50.2% with an average application efficiency of 53.3% (Table 4.11). The efficiency at Awash Melkasa scheme has a trend of decreasing as it moves from head to tail of the scheme. This might be due to the physical property of the soil, which tells us that water-holding capacity at the head is better than at the tail of the scheme. The type of soil texture is loam, and the compactness of the soil in the study area (which may reduce deep percolation losses). This shown that, while using the same farming system, irrigation water application techniques, and field operating strategies, the efficiency of field application differs from field to field. The on-field water management may account for this variation.

Table 4. 11: Application Efficiency for Waqemiya Tiyo and Awash Melkasa irrigation schemes

Field location	Waqemiya Tiyo irrigation scheme			Awash melkasa irrigation scheme		
	Applied Depth (mm)	Moisture stored (mm)	Application efficiency (%)	Applied Depth (mm)	Moisture stored (mm)	Application efficiency (%)
Head	60.4	31.8	52.7	46.9	24.3	51.7
Middle	64.2	30.4	47.4	49.1	28.4	57.9
Tail	40.7	27.9	68.6	48.4	24.3	50.2
Average			56.2			53.3

The average values of application efficiencies for middle and downstream reaches were within the ranges indicated in many literatures reported for surface irrigation.(FAO, 1989), (Rogers et al., 1997) and USA SCS reported that the maximum attainable application efficiency for surface irrigation systems is 55-70%. The average field application efficiencies obtained in this study were within the recommended standard mentioned above for two irrigation schemes. The main reason might be the applied water is less than the soil moisture deficit, farmers used closed-end furrow (which may minimize runoff losses), the results of this study's application efficiency tests indicate that daily operations and on-field water management need to be improved.

4.4.2. Storage Efficiency (Es)

The advantage of storage efficiency is determining that the applied irrigation water has satisfied the crop root zone's moisture deficit. Mean water storage efficiency (Es) were computed using equation (3.12) the result obtained for water storage efficiencies at Waqemiya Tiyo irrigation scheme of the selected fields at head, middle and tail end plots were 50.5%, 48.3% and 47.6% with mean value of 48.8%. whereas, at Awash Melkasa irrigation scheme selected fields at head,

middle and tail end plots were 40.6%, 46.1% and 45.6% with mean value of 44.1% respectively. And maximum storage efficiency recorded in the head at Waqemiya Tiyo at scheme which is 50.5% whereas, at Awash Melkasa 46.1% recorded in the middle of the scheme. The result implies about 44.1% of the soil moisture deficit of Awash Melkasa irrigation scheme were satisfied.

Table 4. 12: Storage Efficiency for Waqemiya Tiyo and Awash Melkasa irrigation schemes

Field Location	Waqemiya Tiyo irrigation scheme			Awash Melkasa irrigation scheme		
	SMS (mm)	RAW (mm)	Es (%)	SMS (mm)	RAW (mm)	Es (%)
Head	30.0	59.4	50.5	24.3	59.8	40.6
Middle	30.4	63.0	48.3	28.4	61.6	46.1
Tail	27.9	58.6	47.6	24.3	53.3	45.6
Average			48.8			44.1

According to Raghuwanshi & Wallender, (1998). Recommended that the water storage efficiency for furrow irrigation systems is 60-70%. Thus, the storage efficiency of the scheme indicated that the irrigation system is poor in fulfilling the soil moisture required for good productivity of the crops. Whereas, at Waqemiya Tiyo irrigation scheme 48.8% this is a clear indication of the stress on soil moisture and the inadequate irrigation water applied. The primary causes could be that farmers applied irrigation water at rates that were faster than soil infiltration, below the expected water demand, or because they were unaware that various crops required varying amounts of water.

4.4.3. Water Distribution Uniformity (DU)

It helps to achieve uniform crop stand and growth on a selected field when irrigation water is applied uniformly. The distribution uniformities of the Waqemiya Tiyo scheme were found to be 89.6, 86.9 and 88.1% in the head, middle and tail end fields, respectively with the average value of 88.2%. (Table 4.13 and 4.14) whereas, at Awash Melkasa scheme found to be 83.5, 82.0 and 91.8% in the head, middle and tail end fields, respectively with the average value of 85.8%. According to the recommendation of Doorenbos & Pruitt (1977). Both the studied irrigation schemes had adequate irrigation water distribution over the entire farm field. The current finding revealed that distribution uniformity was above sufficient, in which 30 and 65% were taken as poor and sufficient, respectively. Whereas, 70% as reported by Raghuwanshi & Wallender, (1998) Thus, the average distribution values of 88.2% and 85.8% at two irrigation schemes indicated the distribution uniformity of irrigation water in the selected farmers' field was sufficient. This might be due to the farmers' practices good land grading in the study area.

Table 4. 13: Total Stored Water at Depth of 90cm in Root Zone (mm) In Waqemiya Tiyo scheme

Field location	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	mean (mm)	least quarter mean(mm)	DU (%)
Head	32.8	33.9	34.3	37.5	27.7	31.1	30.3	29.5	29.9	31.9	28.6	89.6
Middle	36.0	31.8	30.0	32.9	32.6	29.3	28.5	26.5	26.4	30.4	26.4	86.9
Tail	23.9	25.2	32.5	25.5	26.8	27.0	27.1	31.1	31.7	27.9	24.6	88.1
Avg.DU(%)												88.2

Table 4. 14: Total Stored Water at Depth of 90cm in Root Zone (mm) In Awash Melkasa scheme

Field location	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	mean (mm)	least quarter mean(mm)	DU (%)
Head	19.6	25.1	27.0	21.1	24.1	28.4	21.9	25.9	25.9	24.3	20.32	83.5
Middle	51.3	25.8	25.2	23.9	26.0	25.5	22.7	29.7	25.4	28.4	23.30	82.0
Tail	24.3	26.4	23.3	24.0	25.1	22.2	25.6	22.4	25.3	24.3	22.30	91.8
Avg.DU(%)												85.8

4.4.4. Overall irrigation efficiency

According to table 4.15, the overall irrigation efficiencies obtained in this study were 25 and 22% for Waqemiya Tiyo and Awash Melkasa irrigation schemes respectively. Rai *et al.* (2017) suggested that the overall irrigation efficiency values between 50 and 60% are good, 40% are reasonable, while 20-30% is poor. Thus, the overall irrigation efficiencies recorded in this study were poor; the reason might be losses of water in conveyance systems.

Table 4. 15: Overall Irrigation Efficiency for Two Irrigation Scheme

Efficiencies %	Waqemiya Tiyo Scheme	Awash Melkasa Scheme
conveyance efficiency	49.0	45.6
application efficiency	56.2	53.3
Overall irrigation efficiency	27.54	24.30

4.5. External Performance Indicators

4.5.1. Irrigated Agricultural output performance indicators

The irrigated crop area during the study year was 227.5ha However, the designed area was 200 ha as indicated in (Table 18).The cropping pattern indicated that the major part (ha) of the scheme was covered by Tomato which is 125 ha and the rest of 102.5ha of land covered with another crops at Waqemiya Tiyo scheme. Whereas, at Awash Melkasa scheme the irrigated crop area during the study year was 170ha and designed area were 150ha (Table 18).The cropping pattern indicated that Tomato is 80.7ha and the rest of 89.3ha of land covered with another crops at Awash Melkasa scheme. The study revealed that total production of Waqemiya Tiyo was better than Awash Melkasa irrigation scheme this is because of Waqemiya Tiyo scheme has covered more lands with high value crops.

Table 4. 16: Agricultural Output Indicators of Schemes

Irrigation schemes	Waqemiya Tiyo	Awash Melkasa
Designed area(ha)	200	150
Irrigated area during the study(ha)	227.5	170
Production form total irrigated area(US\$)	901480.5	371847.7
Total Irrigation Water Applied(m ³ /season)	1144883.3	832933.7
Crop water requirement (m ³ /season)	995003.4	652643.9
Output per unit irrigated area(US\$/ha)	3962.6	2187.3
Output per unit command area(US\$/ha)	4507.4	2479.0
Output per unit irrigation Supply(US\$/m ³)	0.79	0.45
Output per unit water consumed(US\$/m ³)	0.91	0.57

4.5.1.1. Output per Unit Irrigated Area (OPUIA)

According to the data collected from irrigation scheme the value of output per unit irrigated area is 3962.6 and 2187.3 US\$/ha in Waqemiya Tiyo and Awash Melkasa irrigation schemes respectively (Table 4.18). the study conducted by Değirmenci et al.(2003). In 12 irrigation schemes in the Southeastern Anatolia project suggested that the variation between output per irrigated area various irrigation schemes is in the range of (308-5771 US\$/ha). Thus, the result obtained in this study indicated that the variation of output per irrigated area in two irrigation schemes was in recommended range.

4.5.1.2. Output per Unit Command Area (OPUCA)

This is the other land productive indicator to evaluate the productivity of the scheme from its design command area. The outputs per unit command of Waqemiya Tiyo and Awash Melkasa irrigation schemes 4507.4 and 2479 US\$/ha, respectively (Table 4.18) Değirmenci et al.(2003). Suggested that the variation between the output per unit command area could be in the range of (1223 - 9436 US\$/ha) among various irrigation schemes. Thus, the results obtained in this study showed that the variation between the output per unit command area among Waqemiya Tiyo and Awash Melkasa irrigation schemes was in recommended range. The OPUCA value of both schemes is greater than the value of OPUIA due to the expansion of irrigated land increased beyond the designed or nominal command area of the schemes.

4.5.1.3. Output per unit Irrigation Supply (OPUIS)

This is the water productivity indicator express by output per unit water and indicates how much water diverted for irrigation. The result obtained in this study on output per unit irrigation supply was 0.79 and 0.45 US\$/m³ for Waqemiya Tiyo and Awash Melkasa irrigation schemes

respectively. (Cakmak & Beyr, 2004) conducted a study on sixty irrigation schemes found in Kizilimak Basin, Turkey, and suggested the values for output per unit of irrigation supply could be in the range of (0.03 - 2.21 US\$/m³). Thus, the output per irrigation supply for the two irrigation schemes fell within the recommended range of the cited author.

4.5.1.4. Output per unit of Water Consumed (OPUWC)

This indicates that how much water consumed by crops and how well the total water Consumed by crops is productive. The outputs per unit water consumed for Waqemiya Tiyo irrigation scheme was 0.91 US\$/m³ and Awash Melkasa irrigation scheme was 0.57US\$/m³ (Table 4.18) respectively. Molden et al., (1998) suggested that the output per unit of water consumed for irrigation schemes could be in the range of (0.03 - 0.91 US\$/m³). Thus, the result of output per water consumed for both of irrigation schemes was in the recommended range. The output per unit irrigated area and output per unit command area are termed land productivity. While output per unit irrigation supply and output per unit water consumed is termed water productivity. Therefore, Waqemiya Tiyo irrigation scheme had better land and water productivity than Awash Melkasa irrigation scheme. Therefore, the main reasons for low land and water productivity of Awash Melkasa should be attributed to purely water management at scheme level and farm level rather than other agricultural factors and soil fertility which are nearly same for both schemes under the studies

4.5.2. Water supply Indicator

The relative irrigation supply was 0.57 and 0.64 at two Irrigation Schemes, respectively Molden et al., (1998) .Suggested that the relative irrigation supply value of one is better than the higher or lower values for any irrigation scheme. The result indicated that relative irrigation supply of

both schemes were below one. This implies that both schemes diverted less than the irrigation requirement of the schemes. The result indicates that applied water is not tightly matched to irrigation water demand in the two irrigation schemes. Less relative irrigation supply of both schemes associated with losses of irrigation water in the conveyance system and the expansion of irrigated land without considering the amount of irrigation water.

Table 4. 17: Water Supply Indicator

Irrigation scheme	Total water applied/season (m ³)	Total net irrigation water applied/season (m ³)	Total CWR/season (m ³)	Total IR/season (m ³)	RWS	RIS
Waqemiya Tiyo	584518	549544	995003	960030	0.59	0.57
Awash Melkasa	426798	399808	652,644	625654	0.65	0.64

The relative water supply of both schemes was also less than one, which implies that the sum of irrigation water supply and effective rainfall was not adequate for the crop water requirements of the schemes. The result indicated that the relative water supply was 0.59 and 0.65 at both Irrigation Schemes; respectively. The relative water supply at Awash Melkasa was also higher than the Waqemiya Tiyo Irrigation Scheme, similar to a relative irrigation supply.

4.5.3. Water Delivery Capacity Indicator

The results obtained for water delivery capacities were 0.60 and 0.37 for Waqemiya Tiyo and Awash Melkasa irrigation schemes respectively, According to Molden et al (1998). The value of water delivery capacity below one implied that the designed and constructed canal conveyance capacity does not meet peak consumptive demands in a particular period and constrains the cropping intensities.

Table 4. 18: water delivery capacity for Waqemiya Tiyo and Awash Melkasa schemes

Irrigation schemes	Peak consumptive demand (m ³ /s)	Peak consumptive demand (l/s)	Canal discharge (m ³ /s)	Canal discharge (l/s)	WDC
Waqemiya Tiyo	0.420	420.1	0.250	250	0.60
Awash Melkasa	0.351	351.0	0.129	129	0.37

Thus, the results obtained in this study indicated that the present discharge capacity of the canal at the system head was much lower than the peak crop demand in the two irrigation schemes. Because, during the study period, the main canal did not deliver its full capacity due to there was no assigned body to adjust the distributer leader in main canals in Waqemiya Tiyo irrigation scheme due to high water competition in its water sources. Whereas, higher canal sedimentation at Awash Melkasa scheme thus, Poor canal conveyance system.

4.5.4. Physical Performance Indicators

4.5.4.1 Irrigation Ratio

This indicator reflects the degree to which a specific irrigable area was used during a given production season. The irrigation ratios for two irrigation schemes were, respectively, 1.14 and 1.11. This implies about 114 and 111% of the irrigable command area is currently under irrigation (Table 4.21). This indicates that the irrigated lands in these irrigation scheme areas significantly expanded. Due to the good water resources and land productivity, farmers within the schemes command areas are motivated in irrigating their land. However, the fact that the conveyance system at the two schemes is made of earth material might be the cause of the lower irrigation ratio there. This could contribute to water loss through seepage and the slope is not favored for irrigation water to run a longer distance with minimum flow rate as Compared with

Waqemiya tiyo scheme. Due to this reason, the expansion is less as compared to Waqemiya Tiyo irrigation scheme. According to Agide ,Dejen(2012).As the irrigation ratio of Golgota irrigation scheme and Godino irrigation schemes ranges from 0.67 to 0.92.

Table 4. 19: Physical Performance Indicators for Both Schemes

Irrigation schemes	Initial irrigated area(ha)	Currently irrigated land(ha)	Designed area(ha)	Irrigation ratio	Sustainability of irrigated area
Waqemiya Tiyo	227.5	212.5	200	1.14	1.07
Awash Melkasa	170	164.01	150	1.11	1.04

4.5.4.2. Sustainability of Irrigated Area

The sustainability of irrigated area indicative about the command area under irrigation is contracting or expanding as compared to the area irrigated initially. The results of the sustainability of the irrigated area for the Waqemiya Tiyo and Awash Melkasa irrigation schemes were 1.07 and 1.04, respectively, as shown in (Table 4.21) above. This indicates that actual irrigated areas during the study season were 107% and 104% of the initially irrigated area in Waqemiya Tiyo and Awash Melkasa irrigation schemes respectively. As a result, the irrigated areas of the schemes were higher than they were initially. According to Pereira et al. (2002) if the computed irrigation ratio value was less than one show that the irrigable area becomes contracted and vise-verse.

4.6. Comparison of the Two Irrigation Schemes

As revealed in tables 4.5 and 4.6 more irrigation water was lost in the conveyance systems of Awash Melkasa than Waqemiya Tiyo irrigation scheme. The reason might be unnecessary grass

cover and stagnation of irrigation water canals, higher canal sedimentation poor operation and maintenance practices. And in (Table 4.21) the irrigated areas were expanding for the two irrigation schemes but, more in Waqemiya tiyo irrigation scheme.

The irrigated land is currently expanded. The relative water supply and relative irrigation supply values obtained were low in two irrigation schemes, As revealed Table 4.19 above, depicting that, disregarding the distribution of the supply, the scarcity of irrigation water was being supplied much less than the demand. Moreover, the water delivery capacity values obtained were also low in two irrigation schemes, implying that the present main canal capacity at the system head was not meet the peak irrigation demand of the system. Since the result obtained for RWS, RIS and WDC were below acceptable values for two irrigation schemes. Awash Melkasa irrigation scheme had relatively better values of RWS and RIS than Waqemiya Tiyo irrigation scheme due to less expansion of irrigated land as compared to Waqemiya Tiyo irrigation scheme however, Waqemiya Tiyo irrigation scheme had better canal conveyance system relatively. The land productivity of Waqemiya Tiyo irrigation scheme was higher than Awash Melkasa irrigation scheme. This might be happened due to differences in irrigated field productivity during the study season because of the variation in crop pattern and willingness of farmers to invest more agricultural inputs such as fertilizers, pesticides and herbicides, which means higher yield per unit of land at Waqemiya Tiyo irrigation scheme. Moreover, highly productive and marketable crops such as Tomato and Onion were dominant crops in Waqemiya Tiyo scheme. From this evidence, therefore, the Waqemiya Tiyo irrigation scheme had better land productivity than Awash Melkasa irrigation scheme.

The result obtained for output per unit of irrigation supply and output per unit of water consumed were better in Waqemiya Tiyo irrigation scheme than Awash Melkasa irrigation scheme. This

implied that more outputs were returned from unit irrigation water applied and water consumed from Waqemiya Tiyo irrigation scheme than Awash Melkasa irrigation scheme. The reason might be the irrigated crops were high value crops in Waqemiya Tiyo irrigation scheme; better soil fertility; farmers' awareness and motivation for irrigation. Therefore, Waqemiya Tiyo irrigation scheme had better water productivity than Awash Melkasa irrigation scheme. Waqemiya Tiyo irrigation scheme had significantly better land and water productivity than Awash Melkasa irrigation scheme due to use of high value crops, better agricultural inputs and removal of grass cover and sedimentation from canal systems. Hence, Waqemiya Tiyo irrigation scheme was better performing than Awash Melkasa irrigation scheme. Therefore, adopt the best practices learned from Waqemiya Tiyo irrigation scheme for the Awash Melkasa scheme. Moreover, properly maintain malfunctioned infrastructures, create WUAs and agricultural experts, and create awareness for farmers and WUAs on irrigation water management in two irrigation schemes.

4.7. Irrigation Duration and Irrigation Scheduling

The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation. Hence the depth of irrigation water applied and the soil's basic infiltration rate was used to determine the allowable irrigation duration as indicated in table 4.22 below. The soil types of study area were Loam and Clay loam the bulk density reveals that the soil is compacted. So it is recommended to use irrigation for a long time at a slow flow rate. The measured depth of the irrigation water that farmers had applied to each selected field at the head, middle, and tail end was 60.36mm, 64.19mm, and 40.65mm per interval and they used fixed irrigation intervals of 13, 13, and 14 days respectively in Waqemiya Tiyo irrigation scheme. Whereas, in Awash Melkasa irrigation scheme the measured

depth of the irrigation water that farmers applied to selected fields at the head, middle, and tail end was 46.92mm, 49.35mm, and 30.30mm per interval and used fixed irrigation intervals of 10, 11, and 11days respectively

The farmers practiced fixed irrigation intervals for all crops because they have no the concept of Crop water requirement and continue until the furrows store some amount of water by thinking that it can help until the next irrigation. Generally, the depth of irrigation water and irrigation intervals that farmers practiced was not proportional to the allowable depth of irrigation water and irrigation intervals in both irrigation schemes the cause could be that farmers receive irrigation water on a rotational basis, unaware of irrigation scheduling, and lack water management.

Table 4. 20: Comparison between Farmers' irrigation time and expected time of irrigation

Scheme	Field Location	Depth of water applied (mm)	Time used by farmer to irrigate (hours)	Time expected to irrigated (hours)
Waqemiya Tiyo	Head	60.36	4.7	6.0
	Middle	64.19	4.5	6.4
	tail	40.65	4.7	4.1
Awash Melkasa	Head	46.92	2.2	4.3
	Middle	49.35	2.9	4.5
	tail	30.30	2.8	2.8

4.8. Improvement Options

The following improvement options are made for the improvement of the performance of the schemes to utilize the designed potential at both schemes under the study based on the results and field observations;

4.8.1. Improve Institutional Constraints

Lack of clear mandates and responsibilities of key stakeholders is one of the institutional constraints in small scale irrigation development (Abebe & Sisay, 2020) thus, stakeholder's at Woreda, zonal and regional should give Emphasizes for the improvement of this small-scale irrigation scheme as it has lack of the physical infrastructure to deliver water to irrigated land. Such that design and construction of irrigation scheme and technical constraint. Thus consideration from government has a great role in improvement of this small scale irrigation scheme. Development agents (DA) and Woreda should have to coordinating with zone and regions as well as Strong linkage between stakeholder's and government in the irrigation water management, irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities.; adequate community involvement and consultation in scheme planning, construction and implementation of irrigation development would improve. In conclusion Water distribution and scheduling implemented by farmers differ from designers' recommendation on all schemes, farmers dug new canals and/or increased the discharge capacity of existing canals to allow the current water distribution, as both schemes near to high water potential Awash River. Any stake holders and government give consideration for this irrigation scheme in order to maximize the irrigated area within the available funds. And get good irrigation management, development activity and opportunity for implementing multiple use water systems

4.8.2. Training on irrigation water use efficiency

Water use efficiency is an important concept that when applied at farm level can have a notable impact on water use and quality(Gaius Eudoxie, Bryan Smi th, 2020).training needs of the

beneficiary communities were identified in all areas related water management, operation and maintenance, input supply, and output marketing. Thus low attitude of farmers for deficit irrigation and lack of training on water use efficiency were the main causes for contraction of the command area, especially at Awash Melkasa scheme. In addition, users' belief that productivity increases when excess water applied at farm level. Subsequently, farmers around Awash River almost no scarcity of water rather design and construction irrigation structure (irrigation scheme), water management problem seen widely around study area. Hence, the life of the community of the area depends on the agriculture production due to water access from Awash River found around the area. If the training was not provided to the users, may create many problems in the nearby future

4.8.3. Fixing schedule for operation and maintenance of the canals

Even if the schemes managed by water user associations having written legal bylaws, the implementation was so weak. There is no fixed set schedule for canal clearances, reasonably the users perform canals clearing and maintenance work whenever they feel necessary. These characteristics both schemes as poor maintenance to excess water diversion at the head and unfair water distributions at the tail in the irrigation schemes, this problems is serious at Awash Melkasa scheme. Householder farmers of Awash Melkasa said that the existing irrigation schemes are those made of locally available materials with local knowledge. In addition, the transportation schemes are earthen and not constructed in accordance with the discharge they have to convey. In line with these, the irrigation water supply has been acutely affected. The main canals continual distracted by erosion, siltation, animals and human activities, extremely high labor demand to maintain and clean irrigation canals, considerable loss of irrigation water from Awash Melkasa canals due to seepage and easy destruction of canals by heavy rains. And

there was very limited institutional support in accessing integrated extension services to crop, livestock, and land water management activities in the area. The results were extremely poor at the Awash Melkasa scheme in both schemes where the currently irrigated area was lower than the designed command area. This is mainly due to scheme were earthen and not constructed in accordance with the discharge they have to convey and the maintenance problems of the schemes where water not reaches the tail users. The majority of canals were covered by grass and weeds and soils deposited. Because the water user associations can't perform, the operation and maintenance work on the regular basis. Additionally, in Awash Melkasa SSI scheme lack of regular canal maintenance and grass vegetated of the main, tertiary canals were added for low conveyance efficiency.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

This study was conducted to evaluate the performance of Waqemiya Tiyo and Awash Melkasa irrigation schemes located in East Shewa Zone, Oromiya Ethiopia. Based on Comparative performance evaluation of irrigation schemes to identifying performance gaps of schemes relative to one another, evaluate and improve the production level. The development of community managed irrigation schemes are mainly focused on the expansion of the physical structures. Little attention has been given to evaluating the performance of the existing schemes on a seasonal basis and management practices using indicators. The same is true for two irrigation schemes. Performance was evaluated, using internal and external performance indicators. Those internal indicators used were conveyance efficiency, application efficiency, storage efficiency, distribution uniformity and overall efficiency. The standardized performance indicators established by IWMI were used for external performance are agricultural output, water supply, water delivery capacity and physical indicator. The internal performance evaluation of both schemes undertakes in three selected farms from each scheme. By collecting representative soil samples, analyses of the physical characteristics of the soil, such as its bulk density, textural class, field capacity, and permanent wilting point, have been performed. From the analyses of the indicators, the results of application efficiencies for two irrigation schemes indicated the need for improvements in on-field water management. The water storage efficiency results of the two schemes show that the applied water had not satisfied the soil moisture deficit.

In this study the calculated average value of conveyance efficiency at the main and tertiary canals were 88.5 and 55.4% respectively, at Waqemiya Tiyo scheme. Similarly, Awash Melkasa irrigation scheme at (main canal-1 and 2) 81.7, 79.3 and 57.8, 55.4, % respectively, the results of

analyses revealed that average field application, water storage and overall irrigation efficiencies were 56.2&53.3%, 48.8&44.1% and 27.5&24.3% for two irrigation schemes respectively. The values of relative water supply and irrigation supply were 0.59 and 0.57 for Waqemiya Tiyo scheme, whereas 0.64and 0.65 for the Awash Melkasa Scheme, respectively, these values showed that the applied water was not satisfied the crop water demand. In addition, the water delivery capacity of Waqemiya Tiyo and Awash Melkasa irrigation schemes were 0.60 and 0.37, respectively, Values indicated there is a problem of removal the grass cover and sedimentation from canal systems. The values of output per unit irrigated area were 3962.6 and2187.3 US\$/ha, similarly the output per unit command area was 4507.4 and2479.0 US\$/ha for Waqemiya/tiyo and Awash melkasa schemes respectively. The output per unit irrigation supply and output per unit water consumed were 0.79,0.91US\$/m³ and 0.45,0.57US\$/m³ Waqemiya Tiyo and Awash Melkasa schemes respectively. Likewise, the physical indicators such that irrigation ratio and Sustainability of irrigated area showed that 1.14 and 1.07 for Waqemiya Tiyo and of 1.11 and 1.04 Awash Melkasa scheme respectively. The performance gaps in this irrigation schemes was asses by relevant data were collected from the schemes. Nevertheless, at fieldwork poor water management activity, Lack of clear mandates and responsibilities stakeholders, training on water use efficiency and operation and maintenance work on the regular basis.

5.2 Conclusion

Comparative performance evaluation provides clear information on performance level of the schemes that enables to transfer best practices to take improvement measures. The results of internal performance indicators indicated that two irrigation schemes were performing inefficiently and inadequately. The main reason might be the applied irrigation water was below the crop water demand or farmers lack awareness of different crops need different amounts of water, high sedimentation and illegal water turnout in main and tertiary canals and water stagnation, grass cover in canals waterway, and widening of tertiary canals size and unreasonable losses of water in conveyance systems. But, the irrigation water was distributed uniformly within the field in two schemes. The reason might be the farmers use short-length furrows. Results obtained for external performance indicators revealed that the applied irrigation water is not tightly satisfied the crop water demands and peak consumptive use. The reason might be poor field water management; failure in infrastructures unacceptable losses of irrigation water in conveyance systems; irrigation intensification from neighboring farmers and illegal water turnout Lack of regular canal maintenance and grass vegetated in main and tertiary canals. However, the irrigated lands were expanded in two irrigation schemes. Moreover, the results of output per unit command area were better than output per unit irrigated area in two irrigation schemes; this is evidence that there is an effect thereby expansion of the irrigated area. However, No water supply limitation at both schemes. But, the great challenge was failure in infrastructures and poor field water management. The result of output per unit of water consumed was better than output per unit of irrigation water supply for two irrigation schemes, this is evidence that the lack of awareness to apply the crop water demand may affect the irrigated agriculture outputs.

Generally, based on comparative performance indicators irrigated agricultural output and water delivery capacity performing better at Waqemiya Tiyo irrigation scheme. So, Waqemiya Tiyo irrigation scheme had better performance than Awash Melkasa irrigation scheme. The reason might be higher value crops were irrigated dominantly, more intensive irrigation, and better agricultural inputs in Waqemiya Tiyo irrigation scheme. Hence, the stakeholders in Awash Melkasa irrigation scheme adopt the best practices shared from Waqemiya Tiyo irrigation scheme. However, two irrigation schemes need improvement measures.

5.3 Recommendations

- Water conveyance efficiency of the scheme is low. Hence, the conveyance systems should be enhanced through regular canal cleaning and maintenance of broken irrigation infrastructures.
- The diverted water is below the capacity of the main canal and not meets the demands of the irrigable land so the diversion structure should be built and needs inter networked institutional arrangements to solve irrigation structure problem around study area.
- As, the life of the community of the area depends on the agriculture production due to water access from Awash River. Create awareness to beneficiary farmers about irrigation water management strategies.
- Adopt the best practices learned from Waqemiya Tiyo irrigation scheme for the Awash Melkasa irrigation scheme; for example, use more productive crops, better agricultural inputs, removal of grass cover and sedimentation from canal systems, etc.

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APPENDICES

Table 1: Monthly Climate Data and ETO CROPWAT 8.0 Output

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo	Total Rainfall	Effective Rainfall
	°C	°C	%	km/day	hours	MJ/m ² /day	mm/day	mm/month	mm/month
January	11.3	28.4	73	70	8.1	19.6	3.71	13	0
February	10	28.8	68	70	8.1	20.8	4	21.5	2.9
March	10.4	28.6	74	70	8.4	22.3	4.27	42.9	15.7
April	9.8	27.7	78	70	8.1	22	4.16	78.7	39
May	9.8	26.9	93	70	8.4	21.9	3.94	101.2	57
June	10.5	26.7	91	95	6.3	18.3	3.41	127.4	77.9
July	11.4	26.4	92	52	5.4	17.1	3.22	145.1	92.1
August	10.9	26.2	92	35	5.5	17.7	3.3	155	100
September	10.5	26.3	94	70	5.2	17.3	3.22	139	87.2
October	10.7	26.3	89	70	8.1	21	3.72	90.4	48.3
November	11.7	27.4	77	86	8.5	20.4	3.73	15	0
December	13.9	27.5	72	86	8.2	19.3	3.66	6.6	0
Total								935.8	520.1

Appendix A: Results of soil physical properties in study schemes

Table 2: Cumulative and Basic Infiltration Rates in Waqemiya Tiyo irrigation scheme

Elapsed time (min)	Cumulative time (min)	Water level reading (mm)		Depth of Intake water (mm)	Basic infiltration rate (mm/hr)	Cumulative infiltration (mm)
		Before filling	After filling			
0	0		120.2	0		0
5	5	112	110.3	8	98	8.2
5	10	103.8	104.3	7	78	14.7
10	20	97.3	97.7	7	42	21.7
20	40	90.3	90.7	7	22	29.1
20	60	83.3	81.4	6	17	34.6
30	90	75.9	76.8	6	13	41
30	120	70.4	69	6	11	46.5
30	150	64	64	5	9	51.5
30	180	59	59	5	9	56.5
30	210	54	54	5	9	61.5

Table 3: Cumulative and Basic Infiltration Rates in Awash Melkasa irrigation scheme

Elapsed time (min)	Cumulative time (min)	Water level reading (mm)		Depth of Intake water (mm)	Basic infiltration rate (mm/hr)	Cumulative infiltration (mm)
		Before filling	After filling			
0	0		107.4	0.0		0
5	5	99.7	96.9	7.7	92.4	7.7
5	10	92	94.2	4.9	58.8	12.6
10	20	87.1	89.2	7.1	42.6	19.7
20	40	80	77.3	9.2	27.6	28.9
20	60	70.8	67.3	6.5	19.5	35.4
30	90	64.3	67.2	7.2	14.4	42.6
30	120	61.2	60.5	6.0	12.0	48.6
30	150	55.2	55.2	5.3	10	53.9
30	180	49.9	49.9	5.3	10	59.2
30	210	44.6	39.3	5.3	10	64.5

Table 4: Soil FC, PWP, TAW, and RAW in Waqemiya Tiyo Irrigation Scheme

Filed location	Soil depth (cm)	FC (%)	PWP (%)	TAW (mm/m)	TAW (mm/root depth)	RAW (mm/root depth)
	0-30	39.6	22.6	163.3	49.0	19.6
Head	30-60	39.4	22.9	164.6	49.4	19.8
	60-90	39.6	22.8	167.3	50.2	20.1
Total	90			165.1	148.6	59.4
	0-30	36.5	18.8	177.5	53.2	21.3
Middle	30-60	39.1	20.8	183.2	55.0	22.0
	60-90	42.6	26.1	164.7	49.4	19.8
Total	90			175.1	157.6	63.0
	0-30	34.8	18.7	160.8	48.2	12.1
Tail	30-60	38.0	20.5	175.4	52.6	13.2
	60-90	37.7	18.4	179.1	53.7	13.4
Total	60			168.1	100.9	38.6

Table 5: Soil FC, PWP, TAW, and RAW in Awash Melkasa Irrigation Scheme

Filed location	Soil depth (cm)	FC (%)	PWP (%)	TAW (mm/m)	TAW (mm/root depth)	RAW (mm/root depth)
	0-30	40.2	22.1	181.0	54.3	13.6
Head	30-60	41.4	23.7	176.8	53.0	13.3
	60-90	45.3	27.9	174.1	52.2	13.1
Total	60			178.9	107.3	26.8
	0-30	37.4	20.8	175.6	52.7	21.1
Middle	30-60	35.6	18.9	169.8	51.0	20.4
	60-90	36.7	17.8	167.9	50.4	20.1
Total	90			171.1	154.0	61.6
	0-30	39.0	19.2	193.6	58.1	20.3
Tail	30-60	41.3	23.3	185.3	37.1	13.0
	60-90	40.6	23.3	173.1	51.9	18.2
Total	50			189.4	95.1	33.3

Table 6: Soil moisture stored in root zone (mm) for both irrigation schemes

Selected field	Depth of soil sample(cm)	Waqemiya Tiyo scheme Moisture stored	Depth of soil sample(cm)	Awash Melkasa scheme Moisture stored
head	0-30	10.4	0-30	7.59
	30-60	11.7	30-60	8.33
	60-90	9.7	60-90	8.34
total	90	31.8	60	24.26
middle	0-30	9.4	0-30	8.50
	30-60	11.7	30-60	10.12
	60-90	9.3	60-90	9.78
total	90	30.4	90	28.40
Tail	0-30	9.6	0-30	7.12
	30-60	9.7	30-60	8.71
	60-90	8.6	60-90	8.47
total		27.9	50	24.30

Appendix B: Crop water requirement and Irrigation Water Requirements

Table 7: CWR and IR for Waqemiya Tiyo Irrigation Scheme

Crop types	Total growing day	CWR (mm)	Eff. Rainfall (mm)	IR (mm)	GIR (mm)
tomato	115	464.3	14.8	449.1	935.6
onion	110	399.8	14.1	384.7	801.5
cabbage	120	390	18.9	371.1	773.1
pepper	120	413	21	394.1	821.0
potato	115	445.1	18.2	426.2	887.9

Table 8: CWR and IR for Awash Melkasa Irrigation Scheme

Crop types	Total Growing day	CWR (mm)	Eff. Rainfall (mm)	IR (mm)	GIR (mm)
tomato	115	465.6	16.2	446.7	930.6
onion	110	475.9	15.5	460.7	959.8
cabbage	120	499.8	22.1	475.6	990.8
potato	115	372.3	9	363.3	756.9
tobacco	100	441.8	14.9	426.7	889.0

Table 9: FAO Recommended Crop Water Requirements for Different Crops

Crop types	Recommended seasonal Crop Water Requirements (mm)
tomato	400-600
onion	350-550
potato	500-800
cabbage	380- 500
tobacco	400-700

Source: FAO Irrigation and Drainage paper 33 published in 1996 by Doorenbos et.al.

Appendix C: Crop Raw Data for CROPWAT 8.0 Model

Table 10: Tomato Crop Characteristics

Tomato crop characteristics	Growth Stage				
	Initial	Dev.t	Mid	Late	Total
Length of growing season(days)	10	29	38	38	115
Crop coefficient(kc)	0.5		1.25	0.9	
Rooting depth(m)	0.3		1	1	
Depletion level(p)	0.4	0.4	0.4	0.4	
Yield response factor (ky)	0.4	1.1	0.8	0.4	1.05

Table 11: onion Crop Characteristics

Onion crop characteristics	Growth stage				
	Initial	Dev.t	Mid	Late	Total
Length of growing season(days)	12	28	35	35	110
Crop coefficient(kc)	0.5		1.1	0.9	
Rooting depth(m)	0.25		0.6	0.6	
Depletion level(p)	0.25	0.25	0.25	0.25	
Yield response factor (ky)	0.45		0.8	0.3	1.1

Table 12: Cabbage Crop Characteristics

Cabbage crop characteristics	Growth stage				
	Initial	Dev.t	Mid	Late	Total
Length of growing season(days)	30	35	35	20	120
Crop coefficient(kc)	0.5		1.05	0.95	
Rooting depth(m)	0.25		0.5	0.5	
Depletion level(p)	0.35	0.35	0.35	0.35	
Yield response factor (ky)	0.2		0.45	0.6	0.95

Table 13: Pepper Crop Characteristics

Pepper crop characteristics	Growth stage				
	Initial	Dev.t	Mid	Late	Total
Length of growing season(days)	20	30	35	35	120
Crop coefficient(kc)	0.4		1.1	0.9	
Rooting depth(m)	0.3		1	1	
Depletion level(p)	0.3	0.3	0.3	0.3	
Yield response factor (ky)	0.45	0.8	0.7	0.2	1.1

Table 14: Potato Crop Characteristics

Potato crop characteristics	Growth stage				
	Initial	Dev.t	Mid	Late	Total
Length of growing season(days)	15	31	42	27	115
Crop coefficient(kc)	0.5		1.2	0.9	
Rooting depth(m)	0.3		0.6	0.6	
Depletion level(p)	0.25	0.25	0.25	0.25	
Yield response factor (ky)	0.8	0.8	0.7	0.2	1.1

Table 15: Tobacco Crop Characteristics

Tobacco crop characteristics	Growth stage				
	Initial	Dev.t	Mid	Late	Total
Length of growing season(days)	10	30	30	30	100
Crop coefficient(kc)	0.4		1.2	0.9	
Rooting depth(m)	0.25		0.5	0.5	
Depletion level(p)	0.6	0.6	0.6	0.6	
Yield response factor (ky)	0.2	1	0.5	0.9	0.6

For listed above crop characteristic's **Source:** FAO (1993, 1956, 1924 and 1998)

Appendix D: Flow Measurements in Study Schemes

Table 16: Parshall flume discharge & depth relation (Q=lit/sec)

Height ,m	Throat width of the parshall flume, inches							2ft
	1in	2in	3in	6in	9in	1ft	1ft 6 in	
0.02	0.140	0.281						
0.03	0.263	0.526	0.772	1.496	2.504	3.347	4.803	
0.04	0.411	0.822	1.206	2.357	3.889	5.183	7.475	
0.05	0.581	1.162	1.705	3.354	5.471	7.275	10.536	13.745
0.06	0.771	1.541	2.261	4.473	7.232	9.599	13.946	18.233
0.07	0.979	1.957	2.872	5.707	9.155	12.133	17.678	23.154
0.08	1.205	2.407	3.532	7.047	11.231	14.863	21.708	28.479
0.09	1.446	2.889	4.239	8.489	13.448	17.777	26.019	34.183
0.1	1.702	3.402	4.991	10.027	15.801	20.865	30.596	40.247
0.11	1.973	3.943	5.786	11.656	18.281	24.117	35.426	46.654
0.12	2.258	4.513	6.621	13.374	20.885	27.528	40.499	53.390
0.13	2.557	5.109	7.496	15.177	23.605	31.089	45.805	60.442
0.14	2.868	5.731	8.408	17.062	26.440	34.796	51.334	67.800
0.15	3.191	6.377	9.358	19.027	29.383	38.643	57.081	75.452
0.16	3.527	7.048	10.342	21.070	32.433	42.626	63.038	83.390
0.17	3.875	7.743	11.361	23.188	35.585	46.741	69.198	91.606
0.18	4.234	8.460	12.413	25.380	38.837	50.983	75.557	100.092
0.19	4.604	9.200	13.499	27.643	42.186	55.350	82.108	108.842
0.2	4.985	9.961	14.616	29.976	45.630	59.839	88.848	117.849
0.21	5.376	10.744	15.764	32.379	49.167	64.445	95.772	127.107
0.22		11.547	16.942	34.848	52.794	69.167	102.875	136.610
0.23			18.151	37.384	56.510	74.002	110.154	146.355
0.24			19.389	39.984	60.312	78.947	117.606	156.335
0.25			20.655	42.648	64.199	84.001	125.226	166.546
0.26			21.950	45.374	68.169	89.161	133.013	176.985
0.27			23.272	48.162	72.221	94.425	140.962	187.647
0.28			24.621	51.011	76.354	99.792	149.072	198.529

Table 17: Application Depth of Water in waqemiya Tiyo Irrigation Scheme

Field location	Irrigation events	Time (sec)	Irrigation intervals (days)	Head (cm)	Discharge (l/s)	A(m ²)	Applied depth(mm)
head	1	23469	13	9	4.2	1250	78.86
	2	16233	13	9	4.2	1250	54.54
	3	14192.4	13	9	4.2	1250	47.69
Average							60.36
middle	1	14125.8	14	13	7.5	1640	64.57
	2	13899	14	13	7.5	1640	63.53
	3	14107.8	14	13	7.5	1640	64.48
average							64.19
Tail	1	15330	13	8	3.5	1382	39.18
	2	16476	13	8	3.5	1382	42.11
	3	15905.4	13	8	3.5	1382	40.65
average							40.65

Table 18: Application Depth of Water in Awash Melkasa Irrigation Scheme

Field location	Irrigation events	Time (sec)	Irrigation intervals (days)	Head (cm)	Discharge (l/s)	A(m ²)	Applied depth(mm)
head	1	6522	10	9	4.2	560	48.92
	2	5988	10	9	4.2	560	44.91
	3	6258	10	9	4.2	560	46.94
Average							46.92
middle	1	8922	11	10	4.9	857	51.01
	2	8394	11	10	4.9	857	47.99
	3	8580	11	10	4.9	857	49.06
Average							49.35
Tail	1	7698	11	11	5.7	1100	39.89
	2	11274	11	11	5.7	1100	58.42
	3	9342	11	11	5.7	1100	48.41
average							48.91