PERFORMANCE EVALUATION OF AYSERAWM MEDIUM-SCALE IRRIGATION SCHEME AND PERCEPTION OF FARMERS IN MOJANA WEDERA WOREDA, AMHARA REGIONAL STATE, ETHIOPIA

M.Sc. THESIS

BY

HABTAM GETIE NEGASH

HAWASSA UNIVERSITY

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HABTAM GETIE NEGASH

MAJOR ADVISOR: ABRAHAM W/MICHAEL (PhD)
CO-ADVISOR: TEWODROS ASSEFA (PhD)

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This is to certify that the thesis entitled "Performance Evaluation of Ayserwm Medium scale Irrigation scheme and Farmers perception in Mojana Wedera Woreda, Amhara Region, Ethiopia" submitted in partial fulfillment of the requirements for the degree Masters of Science in Water Resource Engineering with Specialization in Irrigation and Drainage Engineering and has been carried out by Habtam Getie Id. No PGIrDr/0011/11 under our supervision. Therefore we recommended that the student has fulfilled the requirements and hence here by can submit the thesis to the department.

______________________	_______________	__________________
Name of Major Advisor	Signature	Date
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Name of Co- Advisor	Signature	Date

DECLARATION

I, Habtam Getie Negash, declare that this is my own work and that it has not been presented and will not be presented to any other University for similar or other degree award, and that all sources of materials used for the thesis have been duly acknowledged.

Name: Habtam Getie

Signature: _____________

Date: _____________

Place: Hawassa University

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LIST OF ABBREVIATIONS AND ACRONYMS

BOWRD	Bureau of Water Resources Development
^{o}C	Degree Celicius
Cm	Centimeter
CIA	Central Intelligence Agency
EIDP	Ethiopian Irrigation Development Plan
ETc	Crop Water Requirement
ETo	Reference Evapotranspiration
FAO	Food and Agriculture Organization
GDP	Growth Domestic Product
Ha	Hector
IDP	Irrigation Development Plan
IFAD	International Fund of Agriculture Development
IIMI	International Irrigation Management Institution
IR	Irrigation Requirement
IWMI	International Water Management Institution
NGO	Non-Governmental Organization
Kc	Crop Coefficient
Km	Kilometer
M	Meter
MSIS	Medium Scale Irrigation Scheme
MoAFS	Ministry of Agriculture and Food Security
MoWR	Ministry of Water Resource
SCS	Soil Conservation Service
SPSS	Statistical Package for Social Science
SSI	Small-Scale Irrigation
WSDP	Water Sector Development Program
USDA	United State Development Agency

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Performance Evaluation of Ayserewm Medium Scale Irrigation Scheme and Farmers Perception in Mojana Wedera Woreda, Amhara Regional State, Ethiopia**Abstract**

Performance evaluation of irrigation schemes plays an important role to identify the gaps and applying essential measures for improvement. This study was conducted to evaluate the performance of Ayserwm medium scale irrigation scheme and farmers perceptionin Mojana Wedera Woreda, Amhara Regional State of Ethiopia using internal and external indictors. To achieve the objectives, primary data were collected throughfiled observation, determination ofsoil moisturebefore and after irrigation, discharge measurements, soil physical properties and household survey, whereas secondary data were collected from different sources. CROPWAT 8.0 model was used to calculate crop water requirement and irrigation scheduling and SPSS version 26 was used to analysis the collected data from household surveys. The selected internal indicators conveyance efficiency, application efficiency, deep percolation ratio, storage efficiency, distribution uniformity and the external indicators agricultural, water use and physical performance indicators. The result of conveyance efficiency, application efficiency, deep percolation ratio, storage efficiency and distribution uniformity were 62.36%, 58.16%, 41.84%, 63.18%, and 86.45%, respectively. Which leads to an overall scheme efficiency of 36.27%. From the analysis of external indicators, the value of output per irrigated area, output per command area, output per unit water deliver and output per unit water consumed were 379,643.5birr/ha, 457,538.2birr/ha, 121birr/m^3 and 96birr/m^3, respectively. The result of water use indicators, which is relative water supply and relative irrigation supply, value were becomes 0.79 and 0.88 respectively. The result of irrigation ratio and sustainability of irrigated area were 1.2 and 2.9, respectively. From the total beneficiary farmers 80 beneficiaries were selected by using random sampling technique. During the assessment of farmer's perception about the irrigation scheme performance, the respondents reported that the major problems that make the performance of the scheme to be poor were overflow of irrigation water on the canal, water theft, maintenance problem, and water shortage and water utilization conflict. Based on the result of this study the performance efficiency of the scheme is poor; it requires applying necessary measures to achieve good performance of the scheme.

Key word: irrigation scheme, performance evaluation, internal indicators, external indicators

1. INTRODUCTION

1.1. Background

Agriculture is the major source of livelihood and employment in developing and underdeveloped countries (Degirmenci, *et al*., 2017). In Africa, agricultural growth is clearly the key to rural poverty reduction and can make an important contribution to achieving the Millennium Development Goal of eradicating extreme hunger and poverty (Rosegrant*et al*., 2006). More than 70% of Africa's poor live in rural areas and depend largely on agriculture for their livelihoods (IFAD, 2011).

Ethiopia is one of the sub-Saharan Africa countries characterized by low standard of living, widespread poverty found in Eastern Africa (Awulachew *et al*., 2007). About 67% of area lies in arid, semi-arid, and 33% covered by humid and semi-humid areas (Kassie 2019). Ethiopia is predominantly an agricultural country where more than 80% of population depends on agriculture (CIA 2017). The country has abundant rainfall and water resources, its agricultural system does not yet fully benefit from the technologies of water management and irrigation (Awulachew*et al*., 2010). Meanwhile, it is already suffering from food shortage because of rapid population growth and chronic drought occurrence in most part of the eastern and northern part of the country (World Bank 2016).The country has 12 river basins with annual runoff volume of 124.4 billion m^3 and an estimated of 2.6 billion m^3 of ground water potential, which makes an average of 1575 m^3 of physically available water per person per year, a relatively large volume. Agriculture depending on rainfall has failed to produce enough food and with increasing rainfall variability, productivity of rain fed agriculture is expected to diminish (Muhammedziyad*et al*., 2019).

In Ethiopia, rainfall is becoming more erratic and unreliable from time to time as a result of global climate change and manmade climate changing factors like that of disturbance of ecosystem, environmental degradation. In this cause the country particularly makes irrigation is the best alternative to enhance food production. Irrigation practiced in Ethiopia was started during the ancient times producing subsistence food crops. However, modern irrigation systems was started in the early 1950's with the objective of producing Industrial crops in Awash Valley (Kassie 2019). In the 1960s, Irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley (Awulachew*et al*., 2007). The present government is planning to expand irrigation industry by introducing new large and small-scale irrigation initiatives (Sarah *et al*., 2012). Currently, the policies and strategies of Ethiopia is giving more emphasis to the irrigation developments especially the small-scale irrigation (SSI) through the Water Sector Development Programs (WSDP) and Ethiopian Irrigation Development Plan (EIDP). Irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia (Awulachew *et al*. 2005). It has the potential to stabilize agricultural production and mitigate the negative impact of variable or insufficient rainfall of the country. 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 (Haile *et al*,. 2015). The irrigation area of the country is 640,000ha. Of these 120,000ha using rainwater harvesting, 383,000ha from small-scale irrigation and 129, 000 ha from medium and large-scale irrigation systems (Awulachew *et al.*, 2010a).

Ethiopia has irrigation schemes in many parts of the country at different scales. Amhara is one of the regional states of Ethiopia. It has high potential both land and water resources. This region is a number of irrigation schemes has designed and constructed for irrigation development. The irrigation schemes developed have covered an irrigated area of 8,469.26 hectares with 17,443 people beneficiaries. Out of this total irrigated area, 5,718.68 hectares is from small-scale and 2,750.58 is from medium-scale irrigation schemes (Awulachew *et al*., 2007). Therefore, Ayserawm Medium-scale irrigation scheme is one of the irrigation schemes established in Amhara region found in North Shewa Zone, Mojana wederaWoreda.

1.2. **Statement of the Problem**

Many irrigation schemes, particularly in least developed and emerging countries, are characterized by a low level of overall performance (Dejen, 2015; 2016). Expanding efficient irrigation development on various scales is one of the best alternatives to provide reliable and sustainable food security. However, many irrigation schemes in developing countries in general and particularly in Ethiopia are performing below their capacity due to a number of limitations: including poor design, construction, operation, maintenance, and ineffective water control and measurement structure installation (Degimene*et al*., 2003, Aklilu 2006 andTesfaye*et al*., 2019).

In addition to the low performance of irrigation projects in the country, evaluation of irrigation projects is not common: lack of knowledge and tools used to assess the performance of projects enlarges to the problem. Poor management of available water for irrigation, both at system and farm level has led to a range of problems and further aggravated water availability and has reduced the benefits of irrigation investments (FAO, 1996). Yakob and Melaku (2006) reported that the performance of many irrigation schemes in Amhara region is far below their potential mainly due to inefficient irrigation water management, poor maintenance and problems associated to input supply and marketing.

Evaluation of the performance of the irrigation schemes is thus necessary to ensure the well- functioning of the scheme, identify gaps and take appropriate strategies. Therefore, improving water management in irrigation scheme is vital to national food and water security. According to Awulachew *et al*. (2010) reported that improving low performing schemes specifically small scale irrigation schemes requires incorporating applied research on irrigated agriculture. Field evaluation play a fundamental role in improving irrigation systems (Luis, 1999). Irrigation scheme performance assessment is energetic to evaluate the impacts of irrigation practices, to identify performance gaps and to improve system performances (Wondatir, 2016). The performance evaluation of the irrigation scheme was used to identify irrigation management practices and system configurations that can be implemented to improve the irrigation efficiency. Understanding the user perceptions and adaptive behavior provides better insights and information relevant to a policy that helps to address the challenge of sustainable agricultural development in the face of variable and uncertain environments (Simane et al. 2016).

The International Water Management Institute (IWMI) developed two types of indicators to evaluate irrigation systems: internal and external indicators. These indicators are developed for performance evaluation of irrigation systems and irrigated agriculture in which the main output considered crop production and the major inputs are water, land and finance. The performance assessment by using performance indicator is a principal approach to improve the scheme performances (Mamuye*et al*., 2015). Many researchers conducted studies on performance evaluation of different irrigation schemes by using different indicators (Solomon, 2016;Zeleke, 2015;Miniebel, 2019). The present study also use some selected indicators to evaluate the performance of the irrigation scheme.

Irrigation projects are widely studied, planed and implemented throughout Ethiopia. However, no attention is given to the monitoring and evaluation of the performance of already established irrigation schemes. Ayserwm scheme one of the Medium irrigation scheme in Ethiopia the performance of this scheme had not been evaluated before this study. Therefore, this study tries to introduce the concept of the selected irrigation performance indicators in order to evaluate the performance of Ayserwm irrigation scheme in North Shewa Zone.

1.3. **Objective of the Study**

1.3.1. General objective

The overall objective of the study was to evaluate the performance of Ayserewm Medium Scale Irrigation scheme and farmers perception in Mojana Wedera Woreda, Amhara Regional State, Ethiopia.

1.3.1. Specific objectives

The specific objectives of this study were:

- ✓ To evaluate the performance of Ayserewm MSI scheme using internal and external indicators.
- ✓ To assess farmers’ perception about the scheme’s performance.

1.4. **Research Questions**

1. How is the overall performance of the scheme?
2. What is the perception of farmers about the scheme performance?

1.5. **Scope of the study**

This research to evaluate the performance of Ayserwm irrigation scheme using internal indicators such as conveyance efficiency, application efficiency, storage efficiency, deep percolation ratio, distribution efficiency and externals agricultural, water use and physical performance indicators in one irrigation season. In addition to this to assesses the farmer's perception about the scheme performance.

Soil and water quality analysis, extent of waterlogging, and analysis for second irrigation season were not done in the study due to lack of funding and shortage of time. However, such studies are important to see the environmental effect of irrigation.

1.6. **Significance of the Study**

This study was primarily provides theinformation's about the performance of the current irrigation scheme for the irrigation users, NGOs, research centers, contractor's and scheme managers. It also provides to different stakeholders; system managers, farmersand policy makers with a better understanding of how a system will be managed. The second ultimate significant contribution is to understand the drawback and best achievements across system levels. And also it will give insights the impacts of intervention and directions for policy makers. Finally, this study have been baseline information for similar studies in the future for the development of new irrigation schemes in other command areas.

2. LETRATURE REVIEW

2.1. Overview of Irrigation

Irrigation is major importance in many countries in terms of agricultural production and food supply (Muhammedziyad*et al*., 2019). The development of irrigation and agricultural water management holds significant potential to improve productivity and reduce vulnerability to climactic volatility in Ethiopia. Irrigation is one means by which agricultural production can be increased to meet the growing demands of food and other services in Ethiopia (Awulachew *et al*., 2005). Irrigation can be defined as an artificial application of water to soil for the purpose of supplying the moisture essential in the plant root-zone to prevent stress that may cause reduced yield and/or poor quality of harvest of crops (Haile *et al*,. 2015). Berhanie (2017) argued that the primary goal of irrigation, from farmer's perspective, is to deliver the volume and quality water required by plants, throughout a season, to optimize plant growth and crop production.

2.2. Irrigation Schemes

There are different criteria's for the classification of irrigation schemes around the world. The main criteria's frequently used for the classification of irrigation schemes are theirrigated area, scale of operation and management types. The most commonly usedclassification is small, medium and large-scale irrigation schemes, though the interpretation of these categories may vary from country to country.According to Ministry of Water Resources of Ethiopia (MoWR, 2002), irrigation development in Ethiopia is classified based on the size of the command area, in three types.

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

Table 2. 1:Types of irrigation schemes based on size of irrigated areas

Types of schemes	Size of the scheme ha	infrastructure	water management
Small-scale	< 200	fixed or improved water control structures made of local material	LocalwaterUser'sAssociation or Irrigation Cooperatives
Medium scale	200-3000	fixed or improved water control and diversion structures	water User's Association or Irrigation Cooperatives
Large scale	> 3000	Fixed or improved water control and diversion structure	mostly state enterprises

Source: Hagos*et.al* (2009)

2.3. **Performance Evaluation of Irrigation Scheme**

Food security in developing countries is aggravated by the rapid population growth and the consequent demand for food. To meet the demand for food, substantial investments in modifying existing irrigation scheme or establishing new ones will be necessary (Morya, 2017).

Performance evaluation is the systematic analysis of an irrigation system and/or management based on measurements taken under field conditions and practices normally used and comparing the same with an ideal one (Ali 2011). The performance of any irrigation system is defined as the measurement the degree to which it achieves anticipated objectivity, therefore it is important to measure and evaluate the success or failure of a given irrigation scheme objectivity and identity specific areas in need of improvement (Cakmak*et al*., 2004).

The ultimate purpose of performance assessment is to achieve an efficient and effective use of resources by providing relevant feedback to the project management at all levels (Molden*et al*., 2004). It can help to determine problems and identify ways and means of improving system performance (Murray-Rust&Svendsen, 2001).According to Molden*et al* (1998), performance is assessed for a varieties of reasons: to improve system operations, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess impacts of interventions, to diagnose constraints, to better understand determinants of performance, to suggest the remedial solution (recommendations) to improve on any aspects that would result in the effective use of water and energy and to compare the performance of a system with others or with the same system over time (Awulachew *et al*,. 2011). Performance evaluation provides different stakeholders (system managers, farmers, and policy makers) with a better understanding of how a system operates (Bouml&Demir 2009).

Performance assessment for any irrigation system is essential to assess how far the goals and objectives set forth at the time of project formulation of the system have been achieved. Assessment of irrigation performances very essential while planning and verifying management strategies for various irrigation schemes whether large and small scale irrigation scheme (Nuru*et al*. 2020).

According to Nalbantoglu and Cakmak (2007), the most significant objective of performance assessment is to achieve an effective and efficient project performance by providing a flow of information to the project management in each stage. Therefore, it contributes the system management in determining whether the performance is satisfactory and, if not, which and where remedial actions need to be taken in order to remedy the situation. Performance evaluation practices are very much essential because of their central role in effective management (Prasad andJayakumar, 2003). The evaluation of surface irrigation at field level is an important aspect of both management and design of the system. (Andreas and Keren, 2002). The principal objective of evaluating surface irrigation systems is to identify management practices and methods that can be effectively implemented to improve the irrigation efficiency.

2.4. **Performance Indicators of Irrigation Schemes**

Performance was measured through the use of indicators, for which data are collected and recorded. The performance assessment by using performance indicator is a principal approach to improve the scheme performances. Zeleke*et al*. (2015) utilized and refined a set of evaluation indicators to describe the water delivery performance of the Metahara large-scale irrigation scheme. Indicators are used to simplify the complex internal and external factors affecting the performance of irrigated agricultural systems.

Lack of adequate knowledge on the operation and management of the system was the main case to achieve poor efficiency and inequity. Korkmaz*et al*. (2009) evaluated the water delivery performance of irrigation system using variables measured on-site. Authors suggested that, to improve the water delivery performance of the system, it is necessary to reduce water conveyance losses, increase the water application efficiency and apply prepare water distribution plans. The common efficiency terms used for on-farm irrigation system evaluation (internal process indicators) include application efficiency, conveyance efficiency, distribution uniformity, storage efficiency, and recently complementary terms such as runoff ratio, deep percolation ratio, are being applied (Jureins*et al*., 2001).

Internal indicators enable comprehensive understanding of the processes that influence water delivery service and the overall performance of a system (Renault *et al*., 2007). External indicators on the other hand evaluate inputs and outputs to and from irrigation schemes. They are generally meant to evaluate the efficiency of resource use (land, water, finance) in irrigated agriculture. Schultz and De Wrachien (2002) described that the aim of performance assessment is to select a small number of powerful, easily observable indicators that allow reliable conclusions to be drawn. The types of performance measures (indicators) to be chosen depend on the purpose of the performance assessment activity (Molden*et al*., 1998).

2.4.1. Internal performance indicators

These indicators examine the field performance of a project by measuring how close an irrigation event is to an ideal one. Field measurements are necessary to characterize the irrigation system in terms of its most important parameters, to identify problems in its function, and to develop alternative means for improving the system (FAO, 1989a). The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal how irrigation is applied to the field. The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field (Feyen and Dawit, 1999).

2.4.1.1. Conveyance efficiency

Conveyance efficiency is defined as the ratio of the amount of water that reaches the field to the total amount of water diverted into the irrigation system. This term is used to measure the efficiency of water conveyance system associated with the canal network, water courses and field channels. Losses of irrigation water in the conveyance system can be a major component of the overall water losses particularly for farms located at significant distances from water sources where the main canals are long and unlined. The conveyance efficiency mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of the canals (Brower and Heibloem 2011).The amount of water lost depends on quality of operation, and maintenance, and the nature of the soil that affects the seepage rate.Conveyance losses are the losses that occur from the point of diversion until it reaches the farmer's fields.It includes evaporation, seepage losses and other leakages such as filling losses (FAO, 1992).

According to Brouwer and Prins (1989), the conveyance efficiency for long unlined canal (>2000m), the conveyance efficiency has been reported as 60, 70 and 80% for sand, loam and clay soil respectively. On the other hand for medium length unlined canals (200-2000m), Conveyance efficiency is 70, 75 and 85% for sand, loam and clay soil respectively; while for short canals (<200m) the magnitude is nearly 80, 85 and 90% for sand, loam and clay soil respectively. The conveyance efficiency values generally reported are 70 and 50% for unlined poorly managed main and field canals respectively, while for the well managed canals are 85 and 80% respectively (MoAFS, 2002).

2.4.1.2. Application efficiency

Application efficiency, is defined as the amount of water beneficially used by the crop divided by the total amount of water applied (FAO, 1989). The field application efficiency mainly depends on the irrigation method and the level of farmer discipline. The efficiency terms determine these components and compare them with the volume of Water actually applied to the field is regarded as application efficiency. Depending on the type of the source, water is diverted, or pumped to a canal or pipe for Conveyance to the farm for distribution and finally for application to the crops in the field. When Water is diverted into any water application system such as furrows, part of the water infiltrates into the soil for consumptive use by the crop, while the rest is lost as deep percolation and as Runoff. Field irrigation efficiencies are influenced by factors such as soil type, field application methods, depth of application and climate. Very high values are achieved in arid climates and where water shortages prevail.

Some indicative value of the average field application efficiency are 50-60%, 60-80% and more than 80% for surface, sprinkler and drip irrigation methods respectively (FAO, 1989). According to Morries and Vicki (2006) the attainable water application efficiency of furrow irrigation system ranges from 60 to 80 % and efficiency of surge flow irrigation system ranges from 65 up to 80 %. The furrow application efficiencies in the Tendaho commercial sugar state farm have been found in the range of 40.28- 76.91% with average value of 56.57 (Shonka, 2015). Similarly, application efficiencies of 75.15% have been found in Methehara commercial estate farms (Habib, 2004).The study conducted on application efficiency of schemes by (Savva and Frenken, 2002) also reported an application efficiency of 70% for furrow irrigation. The application efficiencies of typical well-designed and managed furrow irrigation system is 50-70% (Fitsum 2019).

2.4.1.3. Storage efficiency

Storage efficiency is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root zone. It is an index used to measure irrigation adequacy. This parameter is the most directly related to the crop yield since it will reflect the degree of Soil moisture stress.The storage efficiency is an indicator of how well the irrigation meets its objective of refilling the root zone.Jurreins*et* *al* (2001) expresses adequacy of irrigation turn in terms of storage efficiency and the purpose of an irrigation turn is to meet at least the required water depth over the entire length of the field.(Raghuwanshi and Wallender, 1998) the researcher reported that 63% storage efficiency usually found in typical furrow irrigation systems.

2.4.1.4. Deep percolation ratio

A component of the irrigation applied to a field percolates into the soil below the root zone. Higher deep percolation ratio values are indications of over irrigation. The volume of percolated water in excess of the leaching requirement is considered as lost water and is used to define the efficiency of irrigation. It is expresses the ratio between the percolated water beyond the root zone to the volume of water applied to the field.In Horst *et al.* (2007) reported that deep percolation was very high for continuous flow treatment but small for surge flow irrigations. Roger *et al*. (1997) explained that water lost to percolation below the root zone due to non-uniform application or over-application water runoff from the field all reduces irrigation efficiencies.

2.4.1.5. Distribution uniformity

To fully express the efficiency of an irrigation system, the uniformity of the water applied need to be evaluated. Irrigation water needs to be applied uniformly in a field in order to achieve uniform crop growth. Distribution uniformity is a measure of how uniformly water is applied during an irrigation event. The uniformity of application can have a considerable effect on crop yield and optimum water application. It is closely related with the Advance Ratio, the ratio between the advance time and the time of irrigation. According to Mahmood (2004), under the water application during surge irrigation, the computed distribution uniformity at different experimental site ranges from 63.5 to 92.5% but for continuous irrigation, it ranges from 59.5 to 83.5%. Jurriens*et al* (2001) proposed that distribution uniformity can be defined as the average infiltrated depth in the low quarter of the field divided by the average infiltrated depth over the whole field. Distribution Efficiency of 65% as “sufficient” and 30% as “poor”.

2.4.1.6. Overall scheme efficiency

According to Eticha (2011), irrigation efficiencies are evaluated at scheme or on-farm level for the purpose of identifying the losses that occur in the irrigation system starting at the water abstraction point, through the conveyance system down to water application in the field, to determine the overall irrigation efficiency. According to FAO (1989), a scheme irrigation efficiency of 50–60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20–30% is considered to be poor. The design of the irrigation scheme, the degree of land preparation, skill and care of the irrigator are the major factors influencing irrigation efficiency. Efficiency in the use of water for irrigation consists of various components and takes into account losses during storage, conveyance and application irrigation plots. Identifying various components and knowing what improvements can be made is essential to making the most effective use of the available water. One of the possible approaches is to increase the efficiency and productivity of the existing irrigation systems to optimize water use i.e. less volume of applied water with greater production (Kassaw, 2011). The overall efficiency values (40-50%) commonly observed in other similar African irrigation schemes (Savva andFrenken, 2002).

2.4.2. External performance indicators

External indicators are used to relate outputs from a system derived from the inputs into that system. They provide little or no detail on internal processes that lead to the output. Many indicators used for external performance evaluation can be calculated from secondary data rather than primary data. These set of indicators are designed to show gross relationship and trends and are useful in indicating where more detailed study should take place, where a project has done extremely well, or where dramatic changes take place. External indicators can be best used as part of a strategic performance assessment and benchmarking performance of schemes (Burt and Styles, 2004).

2.4.2.1. Agricultural performance indicators

It expresses output of irrigated area in terms of gross or net value of production measured local or world prices. The selected indicators of agriculture performance are output per cropped area (Birr/ha), output per command area (Birr/ha), output per irrigation supply (Birr/ m^3), Output per water consumed (Birr/ m^3) as the ratio of production per volume of water consumed (Birr/m^3). The agricultural output indicators establish relationship between agriculture outputs with unit land or unit water. Values of output per unit command area higher than output per unit irrigated area indicate that the irrigation intensity in the system is greater than one. Lower value of output per unit irrigation supply if compared to the value of output per unit water consumed indicate that part of water applied to the field is not productive.

2.4.2.2. Water use performance indicator

This deals with the primary task of irrigation managers in the capture, allocation and conveyance of water from source to field by management of irrigation facilities. Indicators address several aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently, and the service aspects of water delivery which include such concepts as predictability and equity. RIS this indicator is useful to assess the degree of irrigation water stress or abundance in relation to irrigation demand. It is the inverse of irrigation efficiency presented by Bos (1997). If the value greater than one, it indicates irrigation supply was beyond the irrigation demand; if it is less than one, the irrigation supply was below the irrigation demand. While if it is equal to one, the supplied amount of irrigation, water was sufficient to demand, i.e. neither surplus nor deficit. Most of the time it is better to have a RIS near one than a higher value.

2.4.2.3. Physical performance indicator

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

2.5. **Crop water and Irrigation water requirement**

Crops need water for transpiration and evaporation. The water need of a crop thus consists of transpiration plus evaporation. Therefore, the crop water requirement (ETc) is also called "evapotranspiration"(FAO, 1986).The crop water requirement (ETc) is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by various crops to grow optimally (FAO, 1986).

Hess (2005) defined crop water requirements the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Computation of Crop water requirements (ETc) requires planting dates, length of growing season, length of each crop development stage and the crop coefficient (Kc)-values at different crop development stages. Kc is in fraction, which is an empirical ratio of crop water requirement (ETc) to reference crop evapotranspiration (ETo).Surendran*et al.* (2015) states that crop water requirement were higher for longer growing season crops than shorter ones. Crop water requirements can be calculated as the difference between crop evapotranspiration and effective rainfall. For agricultural production, effective rainfall refers to that portion of rainfall that can effectively be used by plants. This is to say that not all rain is available to the crops as some is lost through Runoff (Ro) and Deep Percolation (DP).

Reference evapotranspiration(ET_o) is the rate of evapotranspiration from a large area, covered by green grass, 8 to 15 cm tall, which grows actively, completely shades the ground and which is not short of water (FAO, 1998). The only factors affecting ET_o are climatic parameters. There are several methods to determine the ET_o. BlaneyCraddile method, modified Penman-Monteith method, radiation method and pan evapotranspiration method are some of the ET_o estimation methods. The modified penman Montieth method was used to estimate ET_o using CROPWAT software for the present study. This is because; the method has been found more accurate than the other methods (FAO, 1998). For computation of ET_o using CROPWAT software, the FAO modified Penman-Monteith method requires radiation, air temperature, air humidity and wind speed climatic data.

Irrigation requirements (IR) refer to the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirements. Irrigation is required when rainfall is insufficient to compensate the water lost by evapotranspiration. The main objective of irrigation is to apply water at the right time and in the right amount. If irrigation is the only source of water supply for the plant, the irrigation requirement will always be greater than the crop water requirement to allow for the inefficiencies in the irrigation system. If the crop receives some of its water from other sources (rainfall, water stored in the ground, underground seepage, etc.), then the irrigation requirement can be considerably less than the crop water requirement. The irrigation requirement (IR) is one of the principal parameters for the planning, design and operation of irrigation and water resources systems (FAO, 1998).

2.5.1. Irrigation schedule

Scheduling of irrigation application is very important for successive plant growth and maturity. Water is not applied randomly at any time and in any quantity. Irrigation scheduling is the schedule in which water is applied to the field. Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. How much and how often water has to be given depends on the irrigation water need of the crop (Savva and Frenken, 2002). Proper scheduling is essential for the efficient use of water, energy and other production inputs. Irrigation scheduling is the use of water management strategies to prevent over application of water while minimizing yield loss due to water shortage or drought stress. The adoption of appropriate irrigation scheduling practices could lead to increased yields and greater profit for farmers, significant water savings, reduced environmental impacts of irrigation and improved sustainability of irrigated agriculture (Smith *et al*., 1996).

Among the benefits of proper irrigation, scheduling is improved crop yield and/or quality, water and energy conservation, and lower production costs (James, 1988). The objectives of any irrigation system are to deliver irrigation water in the right amount (size, frequency, and duration), at the right place, at the right moment. Management activity is a major component of success for any irrigation scheme (Depeweg, 1999).

3. MATERIAL AND METHODS

3.1. Description of the Study Area

The study area was located in Amhara National Regional State, North Showa Zone, Mojana Wedera Woreda. Which is located 202 km North East direction of Addis Ababa. It is located at Latitude 9^0 54´ 32.44´´to 9^0 54´ 13.73´´ N and longitudes 39^0 29´ 46.40´´to 39^0 29´ 23.45´´E. The area has an elevation of 2703 meter above sea level. The location map of the study area of Ayserwm irrigation scheme is shown in Figure 3.1.

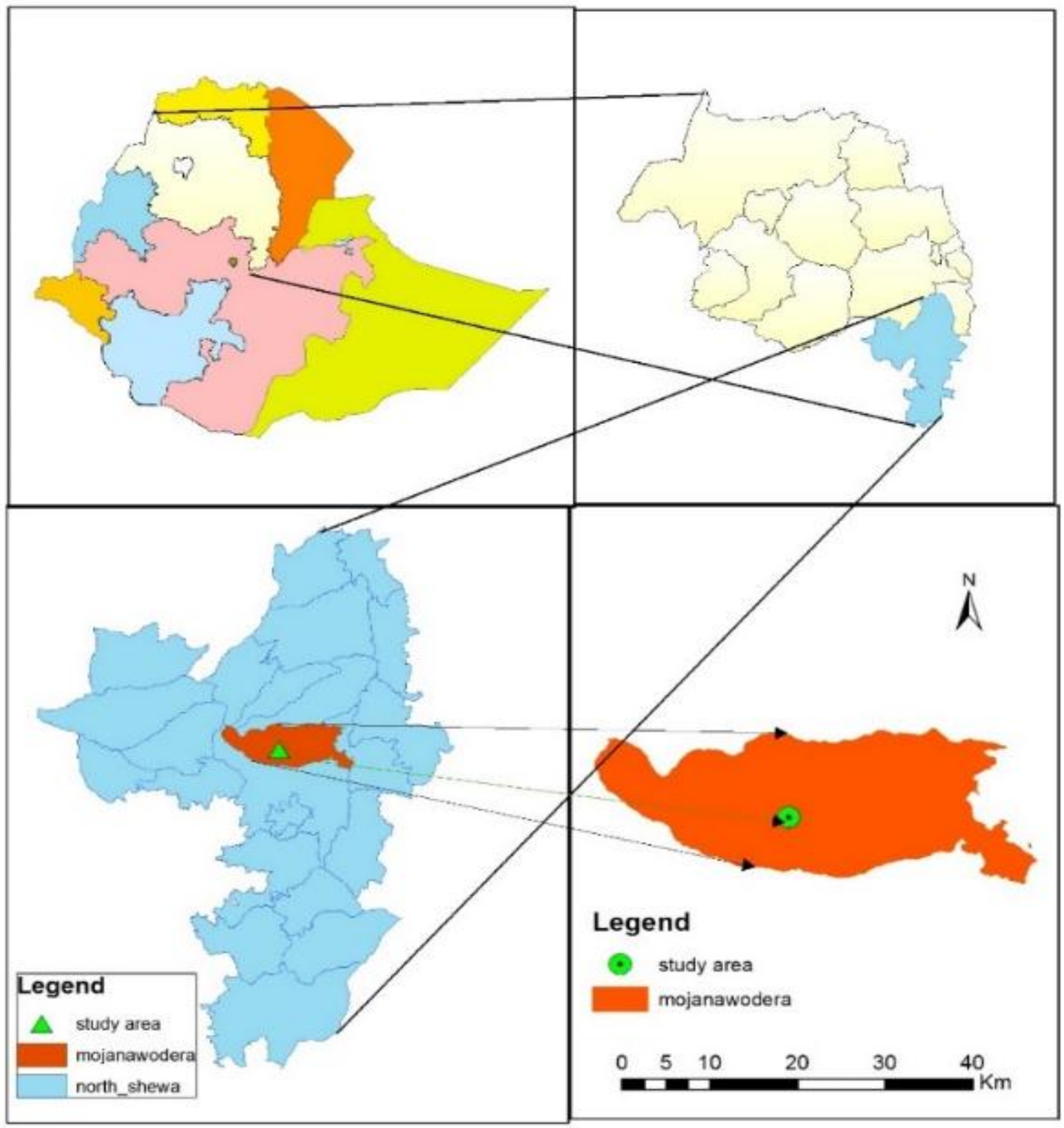

Figure 3. 1:Location map of the study area.

3.1.1. Ayserewm medium-scale irrigation scheme

Ayserewm medium-scale irrigation scheme constructed on Ayserewm River (a river has very small base flow in the dry season) so as to store the rainfall runoff (flood) in the rainy season and to use it for irrigation in dry season. It was constructed in 2007 by Amhara National Regional State Bureau of Water Resources Development (BoWRD). It is found in Amhara Region North Shewa Zone Mojana Wedera Wereda Engda Washa Kebele. Which is located about 17 km east away from the woreda town Sela dingay along the Ayserwm River. Ayserewm River originates from highly elevated mountain range and cross-different rocks of igneous origin the whole project area. The dam is constructed across two volcanic hills with a crust length of 87 .60m and with maximum dam height of 18.00m. At this project, the main canal outlets located in the right side of the dam. It is plan to give service for 20 years of design life sediment load to irrigate the whole command area if the watershed area is as maintained. The spill way is located on the left side of the abutment and joins with natural gullies before natural stream of the dam. In this project, a chute spillway is selected. The selection of this spill way depend on the nature of topography of the area. The total command area of the project is 280 hectare. The irrigation scheme has total 402 household beneficiaries. (Source: Key informant interview result 2021).

3.1.2. Climate

The climate of the study area found in dega agro climatic zone. The area experiences sometimes bi- modal rainfall pattern i.e. belg and meher season rains and it has got windy and cold temperature in most of the months of the year. The main rainy season starts from June 20 and extends through mid-September month and the belg rain is not constant in the area. It starts from February and extends through May month. Therefore, nowadays the belg rain has become decreasing in amount and uneven in distribution. Most of the rainfall of the area is occurs during two months of July and August. The month with very little or no rain is December. The mean annual rainfall is about 942.5 mm. The mean annual minimum and maximum temperatures of the area for the same years were 2.8 and 21.7 ^{O}C, respectively (Source: DebreBerhan Agricultural Research center).

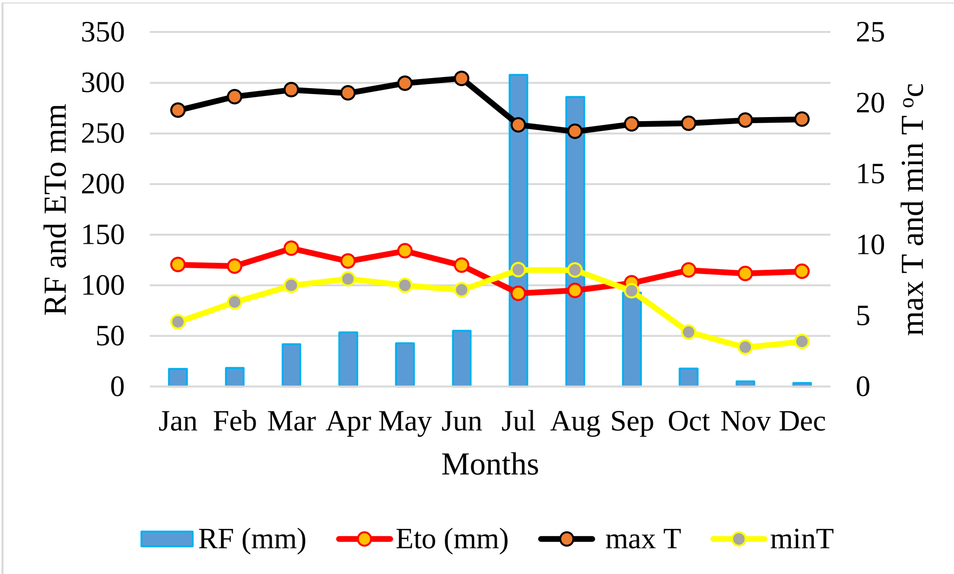

Figure 3. 2:Mean annual rainfall, ETo, maximum and minimum temperature

3.1.3. Soil

The soils of the command area are deep to very deep and dominantly clay textured (vertisole). This type of soil is characterized by waterlogging during rainy Season and soil cracking and swelling during dry period are observed in the scheme (source design document and 2020 laboratory result).

3.1.4. Crop type

The agricultural crop production in the area is grain crop based on double cropping system, depending on the rainfall pattern. Barley, wheat, bean, teff, lentil, chickpea, onion and potato are the major rain fed crops grown in the area.The dominant crops of the area grown under irrigation is garlic, onion, potato, cabbage, tomato and carrot. The type of crops to be grown are selected based on the market condition.

3.1.5. Topography

The topographic features of the study area is gently undulating in the upper parts and almost flat in the lower parts. There are some surface stones and rock out crops in some parts (at the edge) of the command area.

3.2. **Data Collection and Analyses**

3.2.1. Methods of data collection

During the study period, the required data were collected from primary and secondary data sources. The primary data was collected directly from the field measurements, laboratory analyses,field observation, household survey and key informative interview. While the secondary data were collected from design document, Kebele and Wereda agricultural experts office, DebereBerhan Agricultural research center, related journals, published and unpublished materials and FAO documents.

3.2.1.1. Primary data source

Primary data are collected directly from the field. For this study different type of primary data was collected through formal and informal survey approaches. In this study the following primary data were collected.

3.2.1.1.1. Discharge measurements

Discharge measurement is most important data for irrigation scheme performance evaluation indicators. Discharge measurement was taken in order to evaluate canal water conveyance efficiency and farm field water application efficiency. In this study the discharge was determined by using Floating method and two inch parshall flume at canal and farm field respectively.

A. Canal discharge measurement

There are different methods to measure the flow of water in the canal. In this study for the determination of conveyance efficiency the canal discharges were measured by using Floatingmethod. For discharge measurement carefully select control point at canal. At each initial and final point of the selected canals water flow depth, canal width and surface water flow velocity of the main and secondary canals were measured. This Floating method consists of estimating the average flow velocity and measuring of the area of the cross-section.

Average flow Velocity

To determine the average flow velocity, the flow velocity of the water at the surface, Vs 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 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 average 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, Vs the selected length, L was divided by the travel time, t:

$$V_S = \frac{L}{t} \quad \text{---} \quad (3.1)$$

Where: Vs: velocity of the float (m/s)

L: the distance in meters between selected points and

t: the travel time in seconds between selected points

The velocity of the floatmust be reduced in order to obtain the average velocity, because surface

Water flow faster than subsurface water.

$$Va = 0.85 * Vs \quad \text{---} \quad (3.2)$$

Where: Va: the average flow velocity (m/s)

Vs: the surface velocity (m/s)

Area of the wetted cross-section

The area of the wetted cross-section was determined for a selected straight and uniform portion of the canal. Geometry of the Ayserwm irrigation canal is rectangular; so cross sectional area was calculated from measurements of the surface water width and the water depth.

$$A = w * h \quad \text{---} \quad (3.3)$$

Where: A: area of wetted cross-section (m^2)

w: surface water width of the canal (m)

h: water depth of the canal (m)

After determining the average velocity and the cross section area the discharge rate at inlet and outlet of the canals was obtained by equation (3.4)

$Q = Va * A$ -- (3.4)

B. Farm field discharge measurement

Three farmers field were selected at the head, middle and at tail user of irrigation scheme. The criteria for selection of farmers field depends on the distance from source of irrigation water (scheme) and their similarity irrigation practice and crop grown.To determine the amount of water applied by the irrigators to the fields, during an irrigation event, was measured two-inch Parshall flume was installed at the entrance of each field plot to measure the depth of water applied to the field. Frequent readings were taken when the farmers irrigate the test field. Irrigation was continuing until the farmers thought that enough amount of water is applied to the field. When the irrigator completed irrigating the test field, the average depth of irrigation water passing through the flume and the respective time were recorded for the area of test field being irrigated. The discharge was computed using equation (3.5).

$Qf = C\ Ha^n$-- (3.5)

Where: Qf is discharge for free flow condition (m^3/s) Ha is upstream heads of parshall flume (m) C is free flow coefficient, n is exponents for free flow condition, the value of c and n are depend on the throat width of parshallflume. The value of the constant c and n for two inch parshallflume and for metric unit were 0.121 and 1.55 respectively. The minimum and maximum discharge and head range of two inch Parshall flume was 0.18 l/s and 13.2 l/s and 0.015 meter and 0.24 Meter respectively (Gertrudys, 2006).

Figure 3. 3:Determination of cross section of the canal and field discharge using parshall flume

3.2.1.1.2. Soil sampling

Soil samples were collected at the depth of 0-30 and 30-60cm at head, middle and tail users of farmer's field plot for determination of soil physical properties such as soil texture, bulk density, field capacity, permanent wilting point and for after and before irrigation soil water determination.

A. Soil texture and bulk density

To determine soil texture class, the composite samples of disturbed soil were collected from three farmer's field at each of the three locations (head, middle and tail). The maximum effective root zone of vegetable onion is 60 cm (Allen et al., 1998). Therefore, the soil samples at each location were taken at 0-30 cm and 30-60 cm soil depth. The soil samples were taken using Auger. The Soil particle size composition of each particle was determined using hydrometer method in DebreBerhan Agricultural Research Center laboratory.

The hydrometric method of analysis required: weighing balance, sieves (50 microns and 250 microns), 500 ml graduated cylinders, hydrometer (Standard Bouyoucos hydrometer, ASTM NO 152H graduated in gram per liter), thermometer, stopwatch and oscillatory shaker. The soil samples were first air-dried and grinded using pestle and mortar, and then sieved using 50 and 250-micron size sieves. After that 25 gm of soil and 50 ml dispersing agent (40 gm sodium Hex metaphosphate, Napo3 and 10 gm of Sodium carbonate, Na2co3) was mixed in distilled water in 500 ml flask. The soil and solution were then transferred to mechanical stirrer and shake for 5 minutes. The dispersed soil suspension was then transferred to hydrometer jar and the volume in the hydrometer was adjusted to 500 ml by adding distilled water. The readings were taken after 40 seconds and after 2 hours. The results were corrected to a 20 ^{O}C.

For temperature readings above 20 ^{O}C correction values are added to the hydrometer reading, but for temperature readings below 20 ^{O}C correction values are subtracted to the hydrometer reading ISRIC (2000). This is because, for example for the 40 second readings when the temperature is above 20 ^{O}C the movement of particles is high. So, some sand particles may suspend in addition to the clay and silt particles. However, if temperature value is less than 20 ^{0}C the kinetic energy is low and all clay and silt particles may not be suspended. The other correction factor is salt correction. A constant value of 2 is subtracted from every hydrometer reading to correct the effect of salt on the hydrometer results. The results were calculated according to the national soil research center for Ethiopian agricultural research organization (2000) formula as given by equations3.6 to 3.8.

$\% \text{ sand} = 100 - [(d_1 \pm C_1 - 2)\frac{100}{25}]$---(3.6)

$\% \text{ clay} = (d_2 \pm C_2 - 2)\frac{100}{25}$--(3.7)

$\% \text{ silt} = 100 - (\%\text{sand} + \%\text{clay})$---(3.8)

Where:

d_1, d_2 : Hydrometer readings at 40 second and 2 hours respectively

C_1, C_2: Temperature corrections at 40 second and 2 hours respectively

$\frac{100}{25}$: To convert sample weight to 100

2: Salt correction factor

Then, the soil textural class was determined using the USDA textural triangle method for the percent soil fraction as determined from the hydrometric analysis.

Figure 3. 4:Soil texture determination using Hydrometer

Bulk density: - it was determined using undisturbed soil samples were collected by using core sampler at 0 -30 and 30-60 cm depth interval collected from at each of the nine selected locations. The soil samples were placed in containers of knownweight and then weighed. The samples were placed in an oven and dried at 105 ^{0}Cfor 24 hours. After drying, the soil and container were weighed. The dry weight of the soil was divided by the sample volume to determine the dry bulk density. The bulk density is the ratio of oven dried mass of a soil to known volume of core sampler (Blake, 1965).

$$Bd = \frac{Wd}{Vc} \text{--} (3.9)$$

Where: B_d is dry bulk density (gm cm-3),

W_d is the weight of oven-dried soil (gm) and

V_c is the volume of core (cm^3).

B. Soil moisture determination

Soil moisture content measurement is necessary to know the moisture holding capacity of the soil of the command area for different parametric analysis, which have relationship with soil.Irrigation without soil moisture monitoring can be costly, wasteful guesswork. (Stirzaker, 2003). In this study, Soil samples were taken one day before and two days after irrigation. Samples for soil moisture content determination were taken by auger at the selected locations of nine farmer's field. Samples were collected at depths of 0-30 and 30-60cm, and were analyzed in the laboratory using gravimetric method with a view to determine soil moisture content for water stored in the soil. The soil samples were placed in containers of knownweight and then weighed. The samples were dried in an oven for 24hours at temperature of 105°C. After drying, the soil and container were again weighed and the weight of water determined as following. The gravimetric water content was then determined usingthe equation (FAO, 1989).

$$\theta w = \frac{Ww - Wd}{Wd} * 100 \text{--} (3.\ 10)$$

Where: θw= Soil water content on a dry weight basis (%),

Ww= Wet weight of the soil (g),

Wd= Dry weight of the soil (g).

The volumetric water content was calculated from the gravimetric water content using the following expression.

$$\theta V = \frac{\rho b}{\rho w} * \ \theta w * 100 \text{--} (3.11)$$

Where: θv = volumetric moisture content in (%)

ρb = soil bulk density (g/cm3) and

ρw = water density g/cm3 (1g/cm3)

Figure 3. 5: Soil moisture determination using oven dry method.

C. Field Capacity and Permanent Wilting Point

Soil water content at field capacity (FC) and permanent wilting point (PWP) is important for irrigation scheduling assessing, plant water requirement and soil suitability for different land uses (Grewal *et al*., 1990). Field capacity and permanent wilting point of the soil were analyzed through pressure plate apparatus in the laboratory. Soil samples were saturated for one day and a pressure of 1/3 bar (for field capacity) and 15 bars (for permanent wilting point) were exerted until no further change in soil moisture content was observed.

D. Soil Infiltration rate measurement

Soil infiltration refers to the soil's ability to allow water movement into and through the soil profile. It allows the soil to temporarily store water, making it available for uptake by plants and soil organisms. Infiltration rates are a measure of how fast water enters the soil profile.

In this study, the infiltration rate of the soil was determined using double ring infiltrometer.Which consist of two concentric metal cylindrical ring, the inner and outer rings have 30cm and 60cm diameter respectively. Water was added to the soil with certain interval of 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. Infiltration rate is very rapid at the start of water application this called the initial infiltration rate. As more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches a steady rate and this was termed as basic infiltration rate.

3.2.1.1.3. Field observation

Field observations were made to observe the overall field operational activities,the method of water application and know the current practices related to water management techniques made by farmers in the scheme.It was helped to the researcher to know their status and identify constraints the service of the scheme to the target community.

3.2.1.1.4. Household survey and Key informant interview

A. Household Survey

In this study,using beneficiary household survey the researcher assess farmer's perception about the scheme performance, identify key constraints of scheme performance and issues related toplanning and management, maintenance activity of the scheme, sustainability of the scheme, conflict and conflict resolution mechanisms were collected through close ended questionnaires.

Sampling Methods: In this study, random sampling method was used to select respondents from the totalhouseholds at the head, middle and tail users and to evaluate farmer's perception about scheme performance a sample was taken from the users of the irrigation schemes by preparing close ended questionnaires. For data accuracy and validity the questionnaires were prepared by using local language (Amharic). Then the collected data were analyzed using Statistical package for social sciences (SPSS) software by using descriptive statistic and the results were discussed using percentage and frequency in table. The representative sample size was determined using Yamane (1967) provides a simplified formula to calculate sample sizes.

$$n = \frac{N}{1 + N(e)^2} \qquad \text{(3.12)}$$

Where; n is the sample size

N is the population size

e is 10% precision level

$$n = \frac{402}{1 + 402(0.1)^2} = 80$$

Based on the above formula in the study area 80 individual household heads from the irrigation scheme was selected for questionnaires to generate the required information of farmer's perception about Ayeserwm medium scale irrigation performance and to provide the constraints of the performance of the scheme.

B. Key informant interview

Key informative interview was conducted with role model farmers, water user associations,Keble and Woreda agricultural experts. Interview focused on the activities of water distribution system, sustainability of the irrigation scheme, the major problem faced and improvement opportunities of the irrigation scheme, currently irrigated area and crop yield.

3.2.1.2. Secondary data source

The secondary data was collected from design document, Kebele and wereda agricultural experts, DebereBerhan Agricultural research center, related journals, published and unpublished materials and FAO documents. To evaluate the scheme performance the following secondary data was collected.

The long time average climatic data of mean monthly minimum and maximum temperature, rainfall, relative humidity, wind speed and sunshine hours were collected from DebreBirhan Agricultural Research center station and other relevant data like crop coefficient value for each growth stage for the crops grown in the study area, crop root depth, critical moisture depletion, command area were collected from FAO documents, design document and Keble agricultural expert.

3.3. **Data Analysis**

For data analysis activities thestatistical package for social sciences (SPSS) the current version 26 was used to analyze the collected data from household survey, CROPWAT version 8.0 software was used to analyze the crop water requirements and irrigation scheduling for major irrigated crops of the study area and Micro soft excel were used.

3.3.1. Internal performance indicators analysis

3.3.1.1. Conveyance efficiency

The conveyance efficiency of the scheme was computed by taking discharges measurement at different point of the canal. The measurements were taken at initial and final points of main and secondary canals. This term is used to measure the efficiency of water conveyance system associated with the canal network.It was calculated using the equation (Michael 1997).

$$\mathrm{Ec} = \frac{\mathrm{wo}}{\mathrm{wi}} * 100 \quad \text{------------} \quad (3.13)$$

Where: Ec = water conveyance efficiency, %

wo = water flowing at outlet of the canal(m^3/s)

wi = water flowing at inlet of the canal(m^3/s)

Determination of loss in the canal

Conveyance losses refer to the fraction that is lost when irrigation water travels from its source to the field through the conveyance network, including losses due to seepage, leakage and overtopping. It was calculated by the following formula.

$$\mathrm{QL} = \frac{\mathrm{Qi}-\mathrm{Qo}}{\mathrm{L}} * 100 \quad \text{------------} \quad (3.14)$$

Where: Q_L: water loss rate in canal (l/s/100m)

Qi: amount of water delivered to a conveyance system (inflow) (l/s)

Qo: amount of water delivered by a conveyance system (outlet) (l/s)

L: length of canal (m)

3.3.1.2. Application efficiency

To measure how much of the water that is applied is actually retained in the root zone after irrigation, application efficiency was calculated. The ratio of the depth of water added to the root zone to the depth of water applied to the field was measured from three farmers' fields that were growing Garlic.The application efficiencies (Ea) of irrigation at the selected fields were calculated using the equation (Edkins 2006).

$$E_a = \frac{W_s}{W_f} * 100 \quad (3.15)$$

Where: E_a = application efficiency, %

W_s = water stored in the root zone of the plants (mm).

W_f = Water delivered to the irrigated field (mm).

The depth (Ds, mm) of water stored in the soil profile in the root zone was determined using the following equation given by Misra and Ahmed (1990).

$$Ds = \sum_{i=1}^{n} \frac{\text{Mca} - \text{Mcb}}{100} * Di * As \quad (3.16)$$

Where

Mca = Moisture content of ith layer of soil after irrigation on oven dry weight basis, %

Mcb = Moisture content of ith layer of soil before irrigation on oven dry weight basis, %

As = Apparent specific gravity of the ith layer of soil, (dimensionless)

Di = Depth of ith layer, cm and, n = Number of layers in the root zone

3.3.1.3. Deep percolation ratio

The deep percolation ratio computed as the ratio of the percolated water beyond the root zone to the volume of water applied to the field. And also, Deep percolation ratio can be calculated indirectly from values of application efficiency and runoff ratio as given by Feyen and Dawit (1999). In this study, the runoff ratio was normally being considered as zero as the farmers' are using furrows whose tail ends are closed and evaporation from the soil was only a short period after irrigation, so that the parameters were neglected. The deep percolation ratio Calculated using the equationFeyen and Dawit (1999).

$DPF = 100 - E_a - RR$ -- (3.17)

Where: DPF =deep percolation fraction (%)

E_a =application efficiency (%)

RR =runoff ratio (%)

3.3.1.4. Storage efficiency

The storage efficiency is an index used to measure irrigation adequacy.It is the ratio of quantity water stored in the root zone to the quantity of water needed in the root zone before irrigation. The concept relates how completely the water needed prior to irrigation has been stored in the root zone during irrigation. The storage efficiency (Es) was computed as using the equation (Jurriens*et al*, .2001).

$$E_s = \frac{W_s}{W_n} * 100 \text{ ---(3.18)}$$

Where E_s = Water storage efficiency, %

W_s = water stored in the root zone of the plants.

W_n = Water needed in the root zone prior to irrigation

The water needed in the root zone prior to irrigation was computed using (Michael, 2008) equation as:

$$W_n = \sum_{i=0}^{n} \frac{\text{Mfci} - \text{Mbi}}{100} * \text{Ai} * \text{Di} \text{ -- (3.19)}$$

Where: Mfci: moisture content at field capacity in the ith layer of the soil (%)

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

As: Apparent specific gravity of the i^{th} layer of soil, (unit less)

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

n: number of soil layers in the root zone D

3.3.1.5. Distribution uniformity

This shows how uniformly water is applied to the field along the irrigation run. In sandy soils there is generally over irrigation at upper reaches of the run when as in clayey soils, there is over- irrigation at the lower reaches of the run. It is used to measure the variation or non-uniformity of water applied to the entire field.The logic behind the evaluation of water distribution uniformity along the furrow is that when irrigation water is applied into a longer furrow with a given discharge, the upper and the lower ends cannot get equal amount of water (Michael, 1997).

In the study area distribution uniformity of irrigation water in the selected farmer's field was determined by collected soil moisture contentfrom different locations,at each location soil samples were collected at thedepth of 0-30 and 30-60 cm.Then the soil moisture contents of the soils at the selected point were analyzed to determine the depth of water distribution.The collected moisture content from a different location was arranged in descending order, then the mean of least quarter and the mean of total were computed. Merriam and Keller (1978) propose that distribution uniformity be defined as the average infiltrated depth in the low quarter of the field, divided by the average infiltrated depth over the whole field.It was determined by using equation (3.20).

$$DU = \frac{\bar{x}lq}{\bar{x}m} \quad (3.20)$$

Where: DU= water distribution efficiency, %
$\bar{x}lq$= Average infiltrate depth in the low quarter of the field
$\bar{x}m$= Average infiltrated depth over the whole field.

3.3.1.6. Overall scheme efficiency

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

$$E_P = E_c . E_a \quad (3.21)$$

where: E_P= overall scheme efficiency (%),
E_c= conveyance efficiency (%) and

E_a = applcationefficiency (%).

3.3.2. External performance indicators analysis

In this study three external performance indicators were used to evaluate the performance of the irrigation scheme. These are agricultural output, water supply, and physical sustainability indicators, which are proposed by International Water Management Institute (IWMI). For the external performance indicators analysis the following data were needs to analysis. These werereference evapotranspiration, rainfall, crop and irrigation water requirement were needs to analysis.

3.3.2.1. Determination of crop water and irrigation water requirement

The crop water, irrigation water requirements and irrigation scheduling of major irrigated crops in the study area were analyzed by using CROPWAT 8.0 software. The model needs the climatic data, crop and soil data for the determination of crop water and irrigation water requirements. The software uses the FAO (1992) Penman Monteith equation for calculating reference evapotranspiration. To determine ETo value model requires climatic data; mean monthly minimum and maximum temperature (^{0}c), relative humidity (%), wind speed (km/day) and sunshine hours (hr).

After ET_o determination the crop water requirement can be calculated as:

$ETc = ETo * Kc$-- (3.22)

Where: ETc = Crop Water Requirement mm/day

ETo = Reference Evapotranspiration mm/day

Kc = Crop Coefficient varies with crop growth stages

The irrigation water requirement (IWR) was computed after estimation of effective rainfall bythe CROPWAT 8.0 model.

$IWR = ETc - Re$-- (3.23)

Where: IWR = irrigation water requirement (mm)

ETc = Crop Water Requirement (mm/day)

Kc = effective rainfall (mm)

3.3.2.2. Irrigation schedule

For the determination of irrigation schedule of the irrigation scheme to know the current irrigation practices, irrigation method, moisture content, field capacity, permanent wilting point and depletion fraction at each growing stage data was collected. Furthermore, farmer's irrigation practices was determined such as irrigation frequency, interval of irrigation, and application depths. Irrigation interval depends on water depletionrequirement of the crop, rooting depth, soil type and growth stage of the crop.

The totalavailable water (TAW) is the difference between field capacity and permanent wilting point contentsmultiplied by the depth of the root zone (Zr), (Allen *et al*., 1998).

$$TAW = (FC - PWP) * Zeff \text{ -- } (3.24)$$

where: TAW = total available soil moisture (mm)

FC = volumetric moisture content at field capacity (%)

PWP = volumetric moisture content at Permanent point (%)

$Zeff$ = effective root zone of the crop (mm)

$$RAW = TAW * P \text{ --- } (3.25)$$

Where: RAW = readily available water (mm)

P =water depletion fraction/management allowable depletion (%)

I = irrigation interval (days)

$$I = \frac{RAW}{ETc} \text{ --- } (3.26)$$

3.3.2.3. Agricultural performance indicators

For this study, the following agricultural out-put indicators used by (Molden 1998).

$$Out\ put\ per\ cropped\ area = \frac{production}{irrigated\ cropped\ area} \text{ ----------------------------------- }$$

(3.27)

$$Out\ put\ per\ unit\ command\ area = \frac{production}{command\ area} \text{ ----------------------------------- } (3.28)$$

$$Out\ put\ per\ unit\ irrigation\ diverted = \frac{production}{irrigation\ diverted} \text{ ------------------------- } (3.29)$$

$$Out\ put\ per\ unit\ water\ consumed = \frac{production}{volume\ of\ water\ consumed\ by\ ET} \text{ -------------- } (3.30)$$

3.3.2.4. Water supply indicators

Water supply indicators are used to check the water supply and demand for the scheme. Two types of indicators namely relative water supply and relative irrigation supply were calculated by using the following formulas (Perry, 1996).

$$Relative\ water\ supply = \frac{total\ watersupply}{crop\ demand} \text{ --- } (3.31)$$

$$\boldsymbol{R}elative\ irrigation\ supply = \frac{irrigation\ supply}{irrigation\ demand} \text{ -------------------------------------- } (3.32)$$

3.3.2.5. Physical performance indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. The selected indicators used for evaluation of physical performance was irrigation ratio and sustainability of irrigation area. Irrigation ratio, being an indicator used to evaluate the degree of utilization, which the land available for irrigation is also a useful indicator of whether there are factors contributing for under irrigation of the command area. Which can be expressed as the follows (Molden*et al.*, 1998).

$$Irrigation\ Ratio = \frac{irrigated\ croped\ area}{command\ area} \quad (3.33)$$

$$Sustainable\ irrigation\ area = \frac{Current\ irrigable\ area}{initially\ irrigable\ area} \quad (3.34)$$

4. RESULTS AND DISCUSSION

4.1. **Soil data analysis results**

4.1.1. Soil texture and bulk density

The soil textural class of irrigation scheme was determine based on the particle size determination through using USDA SCS soil textural triangle method and the results are presented table 4.1. The sandy, clay and silt fraction of soil varied from 14 to 18%, 36 to 59%, and 22 to 29% respectively. Based on the USDA SCS soil textural triangle method the soil textural class of the study area is characterized by clay soil except at 0-30cm depth of head canal reach was clay loam. Average bulk density at head, middle and tail of canal reaches were 1.19, 1.18 and 1.14 g/cm^3 respectively. In the head reach of the canal slightly greater value of bulk density was recorded compere to middle and tail canal reaches which indicates that the soil has compacted than the middle and tile canal reaches of the irrigation scheme. 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/cm^3, 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/cm^3 which is indicates that there was no compaction and at normal range of organic matter content in order to get better plant growth.

Table 4. 1: Soil textural class and bulk density

Canal reaches	Soil depth (cm)	Particle size distribution (%)			Textural Class	Bulk density (g/cm^3)
		Sand	Clay	Silt		
Head	0-30	38	36	26	Clay loam	1.00
	30-60	36	40	24	Clay	1.37
Average						1.19
Middle	0-30	21	57	22	Clay	1.08
	30-60	19	58	23	Clay	1.27
Average						1.18
Tail	0-30	14	59	2 7	Clay	1.04
	30-60	14	57	29	Clay	1.25
Average						1.14

4.1.2. Field capacity and permanent wilting point

The soil moisture at field capacity varied from 34.73 to 45.17 by volume, while the soil moisture at permanent wilting point varied from 22.37to34.58on a volume basis and the average total available water various from 8.83 to 12.37% at 0-30 and 30-60 cm soil depth intervals and the results are indicates (Table 4.2). FAO (1998) recommended TAW values for clay soil ranges from 120-200 mm/m. Therefore, the estimated average values of TAW for the study area within the acceptable range.The average values of TAW were used as input for estimation of the crop water requirement in the CROPWAT software.

Table 4. 2:Soil FC, PWP, and TAW

Canal reaches	Soil depth (cm)	FC (%)	PWP (%)	TAW (%)	TAW (mm)
Head	0-30	34.73	22.37	12.37	37.1
	30-60	36.37	24.5	11.87	48.77
Total					85.87
Middel	0-30	44.43	34.58	9.85	31.92
	30-60	45	36.06	8.83	33.65
Total					65.57
Tail	0-30	45.17	34.43	10.73	33.46
	30-60	44.3	33.03	11.27	42.25
Total					75.71
Total averages					75.71

Where; Fc=field capacity, PWP=permanent wilting point, TAW=total available water

4.1.3. Soil infiltration rate

Infiltration rates were highest values obtained at the beginning of the experiments, as water application continues and the upper most soils become saturated, the infiltration rate gradually decreases and reaches a nearly constant rate within a times. In this study, the basic soil infiltration rate was 0.7cm/hr. And this value observed at 160 minute.

According to FAO (2001), the recommended basic soil infiltration rate for clay soil is 0.1-0.5cm/hr. However, the observed result of basic soil infiltration is little greater than the recommended value for clay soil. This might be due to the cause of the effect of the nearby borehole, but in general could not capture the exact problems for high infiltration rates. As a result, better to use the average recommended value of 0.3cm/hr input of CROPWAT software for crop water requirement determination.

4.1.4. Determination of reference evapotranspiration

The value of reference evapotranspiration, rainfall and effective rainfall were calculated based on CROPWAT- 8 Software as indicated Appendix (1and 2).The graphical variation of monthly values of ET_o, RF, and effective rainfall is shown figure (4.1). The ET_ovalues from January to June and October to December was larger than the values of rainfall but smaller values observed from July, Augustand September. The maximum and minimum ETo values were 4.4 and 2.97 mm/day in March and July respectively. The monthly ETo values for the study period from November to March 2020/2021 were 3.72, 3.67, 3.88, 4.25 and 4.4 mm/day during November, December, January, February and March respectively. The monthly average ETo values from January to December was 3.79 mm/day. However, the monthly average ETo value for the study period from November to march was 3.98 mm/day. The yearly reference evapotranspiration of the study area was 1382.81mm, while the total ETo value for the study period was 601.05mm.

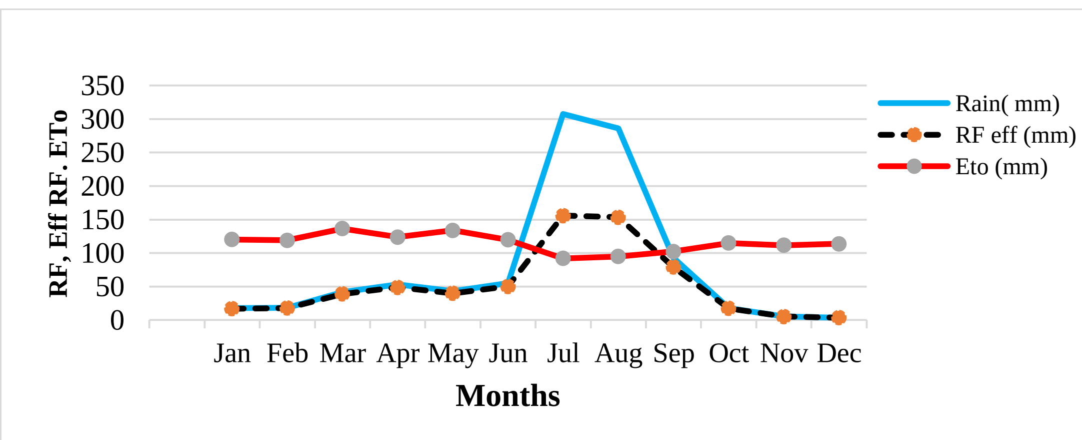

Figure 4. 1:Graphical representation of mean Monthly RF, RF_{eff} and ETo for Ayserwm irrigation scheme

4.1.5. Rainfall data analysis

The scheme has occasional a bimodal rainfall distribution pattern. The total yearly rainfall and effective rainfall of the scheme were 942.5 and 627.7mm respectively as indicated in (Appendix 2). In Ayserwm MSI scheme the average maximum and minimum rainfall values were 307.6 and 3.6 mm occurs at the month of July and December respectively.

4.1.6. Crop water and irrigation water requirements

The crop water and irrigation water requirements for growing crops in the study area were determined by CROPWAT-8 software using the climate, crop and soil data. The major crop grown in the study area were Garlic, onion, Potato, Cabbage, Tomato and Carrot, the crop water and irrigation water requirements of the crop were indicate in Appendix (III to XX1). The total seasonal crop water requirement was 408.5, 322.7, 472.7,482.6, 546.1and 586.0 mm for Garlic, Onion, Potato, Cabbage, Tomato and Carrot respectively. The higher water requirement value observed for carrot, which is 586.0 mm and the lowest requirement value observe for Onion it was 322.7 mm crops. It indicates that the crop water requirement is higher for crops with longer growing seasons than for crops growing short seasons. The variation of crop water and irrigation water requirements for the irrigated crops in the study area indicated in figure (4.2).

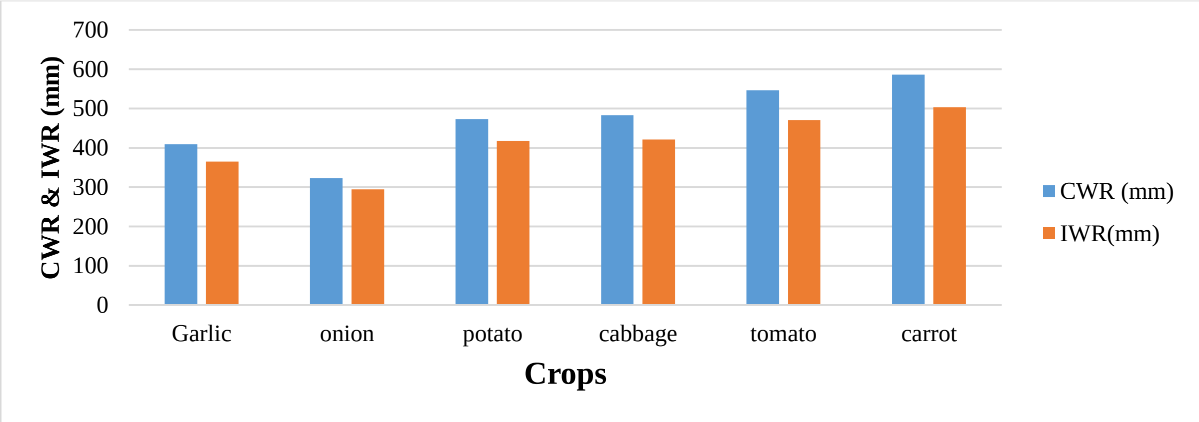

Figure 4. 2: CWR and IWR of irrigated crop in the study period

The total crop water requirement of the irrigation season of Ayserwm scheme was calculated by multiplying CWR of each crop with its area coverage divided by total irrigated area during irrigation season. By using the same calculation procedures, the total net irrigation requirements and effective rainfall of the season also calculated, the result becomes 395.7, 353.7 and 41.6 mm/season CWR, IWR andRFeff respectively. To change the depth to volume, the depth of each value multiply by the total irrigated area. The value of crop water requirement, irrigation water requirement and effective rainfall becomes 1,335,289.6, 1,193,560.6 and 140,379.2 m^3/per season respectively.

4.1.7. Irrigation scheduling

Irrigation schedule is very important to attain the maximum crop yield and water productivity. In Ayserwm irrigation scheme the beneficiary use rigid rotational schedule and the irrigation interval was similar for different crops. The farmers apply constant way of irrigation scheduling during the whole growing season for all crops as indicated in table (4.3). However, crops require different irrigation interval in each growth stage.

Table 4. 3: Farmers practiced irrigation interval and calculated irrigation interval at each growth stage and irrigation frequencies

irrigated crops	Farmers practiced irrigation Intervals (day)	Calculated irrigation intervals (day)				
		Initial	Development	Middle	Late	Frequency
Garlic	8-15	5	6	7	8	19
Onion	8-15	5	6	7	7	17
Potato	8-15	16	14	10	17	11
Cabbage	8-15	16	17	16	17	9
Tomato	8-15	13	13	13	13	12
Carrot	8-15	17	14	12	14	12

4.2. **Scheme Performance Evaluation**

4.2.1. Internal performance indicator results

4.2.1.1. Conveyance efficiency and conveyance losses

The conveyance efficiency value, which indicates that the amount of water lost during transportation of water from the source to the outlet of canal. The water conveyance efficiency in Ayserwm irrigation scheme was computed by using equation (3.13). The computed value of water conveyance efficiency and water conveyance losses in main canal presented in table (4.4). The highest water conveyance efficiency of the main canal was 83.62% in the Mc-4 (1300-1600m) and lower conveyance efficiency was 66.18% in the Mc-6 (2200-3000m). This high and low water conveyance efficiency observed per 100 m main canal lengths.

The overall average calculated value of the lined main canal conveyance efficiency was 70.68% in table (4.4). Which is less than the recommended value by FAO, (1989) for canal length >2000m constructed on clay soil its conveyance efficiency would be 95% for lined canal. The reason of low conveyance efficiency in the irrigation scheme is there was over topping of water in most of the canals due to improper canal design and water was controlled in the traditional manner using stone and mud see (figure 4.3). Additionally, the people who lived around the main canal used canal water for washing clothes, cars and for livestock drinking, these accumulated causes aggravated water losses in the canal.

Figure 4. 3:Overtopping of water on main canal and water control by traditional manner

The conveyance loss per 100 meter length of the main canal atMc-2 (400-800) was high losses than the other section of the main canal. This indicated that give priority of maintenance compared to the other section of the main canal. Renault *et al*. (2007) reported that 10 to 15% of water loss in the canal is accepted. However, the overall water loss result of main canal in Ayserwm irrigation scheme is 29.32%, this result based on the above report it's not inthe acceptable range. This low values may be due to in the cause of evaporation losses, overflow of water on the canal, local water control gates and siltation in canal.

The calculated conveyance efficiency value of secondary canals also show in the table (4.4). The highest water conveyance efficiency of the secondary canal was 63.58% in the

Sc-1 (0-200m) and lower conveyance efficiency was 34.52% in the Sc-4 (0-540m). This high and low water conveyance efficiency observed per 100 m secondary canal lengths. In the Sc4 low value of conveyance efficiency was observed, this occur in the cause of the canal fill with stone and overtopping of water at the canal. It needs an improvement compared to the other section of the secondary canal. The calculated water conveyance loss per 100 meter length of the secondary canal high in Sc-1 (0-200) and low in Sc-3 (600-1450).Leakage of irrigation water through the water control structures and canal sedimentation were the reasons for higher water losses at Sc-1. The overall result of conveyance efficiency in the secondary canal was 54.04% for a length of <2000m lined canal. The result are below the FAO (1989) recommended value which is 95% for lined canal. This low value might have occurred due to poor canal management and unauthorized diversion of water by farmers into field see in figure (4.4).

In general, at Ayserwm irrigation scheme the major cause of high conveyance losses, were canals were designed with small cross section area, which resulted water over flow on the canal, canals were silted with weeds and soils and non-functional of flow control gates. From the result it is concluded that conveyance efficiency of the scheme is poor.

Table 4. 4:Waterconveyance efficiency and conveyance losses

No.Canal	Length of canal (m)	Qin (l/s)	Qout (l/s)	EC (%)	EC%/100m	Wl(%)	Wl (ls^{-1} $100m^{-1}$)
MC-1 (0-400)	400	167.52	160.18	95.62	23.90	4.38	1.83
MC-2 (400-800)	400	134.18	66.48	49.54	12.39	50.46	16.93
MC-3 (800-1300)	500	66.48	46.75	70.32	14.06	29.68	3.95
MC-4(1300-1600)	300	46.75	39.09	83.62	27.87	16.38	2.55
MC-5(1600-2200)	600	39.52	30.83	78.00	13.00	22.00	1.45
MC-6(2200-3000)	800	30.83	20.40	66.18	8.27	33.82	1.30
MC-7(3000-3600)	600	20.40	10.50	51.47	8.58	48.53	1.65
Average				70.68		29.32	4.24
SC-1 (0-200)	200	85.28	54.22	63.58	31.79	36.42	15.53
SC-2 (200-600)	400	54.17	39.10	72.18	18.04	27.82	3.77
SC-3 (600-1450)	850	39.08	22.16	56.71	6.67	43.29	1.99
SC-4 (0-540)	540	89.13	30.77	34.52	6.39	65.48	10.81
SC-5 (0-470)	450	75.87	32.79	43.22	9.60	56.78	9.57
Average				54.039		45.96	8.33
Average conveyance efficiency and losses				62.36	37.64		

Where Mc is main canal, Sc is secondary canal

Figure 4. 4:Poor management of canal and diversion of water by farmers

4.2.1.2. Application efficiency

The application efficiency of scheme shows the amount of water stored in the crop root zone to amount of water applied in field. Water stored in the crop root zone and amount of water applied to farm at the selected field was compute-using equation (3.20) and (3.21) respectively. The average application efficiency of the selected fields at the irrigation scheme was at head, 65.64%, middle, 53.43% and tail, 55.40% with an average water application efficiency of 58.16% given as in table (4.5). According to FAO (1989), reported that average application efficiency for surface irrigation in the range of 50%-60%. Lesley (2002) suggested that the application efficiency of furrow irrigation in the range of 50-80%. Therefore, in the study area water application efficiency value is at recommended value, this implies that the application efficiency of the scheme was efficient.

Table 4. 5:Field application efficiency of Ayserwm medium-scale irrigation scheme.

Canal reach	Applied depth (mm)	Stored depth (mm)	(Ea) %	DPR %
Head	58.98	38.72	65.64	34.36
Middle	47.93	25.61	53.43	46.57
Tail	43.12	23.89	55.40	44.6
Average application efficiency			58.16	41.84

4.2.1.3. Deep percolation ratio

In the study area, the farmers use blocked end furrows, only deep percolation loss at the field was consider. The deep percolation ratio calculated by using equation (3.17). It was at head 34.36%, at middle 46.57% and at the tail 44.6%. In this result, the high deep percolation ratio observed at middle field plot and low at head field plots. High deep percolation ratio observed in low application efficiency. The average deep percolation loss in the scheme was 41.84%. High deep percolation ratio value indicates over irrigation and poor water management.

4.2.1.4. Storage efficiency

This indicator used to know the applied irrigation water satisfied to the moisture deficit of the crop root zone. In this study average storage efficiency at the head, 75.98%, middle, 56.00% and tile 57.55%. The storage efficiency at head location of the field greater than both at middle and tile location. The average storage efficiency of the scheme is 63.18% show in table (4.6). Similar result was reported by (Raghuwanshi and Wallender, 1998) 63% storage efficiency usually found in typical furrow irrigation systems.

Table 4. 6: Calculated storage efficiency of the scheme

Canal reach	Stored depth (mm)	require depth (mm)	Storage efficiency (Ea) %
Head	38.72	50.96	75.98
Middle	25.61	45.73	56.00
Tail	23.89	41.51	57.55
Average storage efficiency			63.18

4.2.1.5. Distribution uniformity

When irrigation water is applied uniformly in a field, it helps to get uniform crop stand and uniform crop growth on the field. The distribution uniformities of the scheme were found to be 89%, 85.18% and 85.16% at the head, at middle and at tail end fields respectively, with the average value of 86.45%. FAO (1992) suggested that in an average rotational supply with adequate management and communication, having distribution efficiency (DU) of 65% as “sufficient” and DU of 30% as “poor”. According to FAO the result of the scheme indicated that the distribution uniformity of irrigation water in the field was sufficient. Similar results have been reported by, Abdaldafi (2006) the result shows that the distribution efficiencies for all cycle ratios were similar which are 84%, 83% and 85% respectively. And also similar results have been reported by (Solomon, 2016) the DU value at head, middle and tail end fields were 86%, 85.25% and 85.02% respectively, with in an average value of 85.42%.

4.2.1.6. Overall irrigation efficiency

Overall efficiency is the product of conveyance and application efficiency. In this study, the overall efficiency of the irrigation scheme was 36.27% shown in table (4.7).According to FAO (1989), a scheme irrigation efficiency of 50-60%is good; 40% is reasonable, while a scheme irrigation efficiency of 20-30% is considered to be poor. Therefore, the overall irrigation efficiency result of Ayserwm scheme indicate slightly poor performance.

Table 4. 7:Calculated overall efficiency

Indicators	Efficiency of the scheme (%)
Conveyance efficiency	62.36
Application efficiency	58.16
Storage efficiency	63.18
Deep percolation ratio	41.84
Distribution uniformity	86.45
Overall efficiency of the scheme	36.27

4.2.2. External performance indictor results

4.2.2.1. Agricultural output indicators

These indicators are used to evaluate the degree of utilization of resource such as water and land in producing agricultural outputs. The agricultural outputs production values calculated from one irrigation season, 2020/2021years and the data requires include crop type, coverage of each crop, average yield and price of each crop shown in table (4.8).

The total proposed irrigable area in the design document of the scheme was 280 hectares. However, in the study time the irrigated area was 337.45 hectares. The major crop cultivated in the Ayserwm irrigation scheme present in table (4.8).

Table 4. 8: Irrigated crop type and output production values

irrigated crops	Area (ha)	yield (Ql/ha)	Total yield (Ql)	Price (birr/Ql)	Production (birr)
Garlic	181.65	95	17256.75	6000	103540500
Onion	102.05	102	10409.1	1000	10409100
Potato	31.5	182	5733	1200	6879600
Cabbage	12.75	209	2664.75	2000	5329500
Tomato	5.5	160	880	1200	1056000
Carrot	4	112	448	2000	896000
Total	337.45	860	37391.6	13400	128,110,700

Where Q is Quintal, 1Q=100kg

I. Land productivity indicators

A. Output per unit irrigated area

This is one of the land productivity indicator express by output per hectare. This indictor evaluates the productivity of the scheme from its currently irrigated area rather than the command area. According to the data collected from irrigation scheme the value of output per unit irrigated area is 379,643.5birr/ha.Tahir (2020) described that the value of output per unit irrigated area for Ketar and Arata chufa irrigation were found as140,356 and 227,124 birr/ha respectively. Dessalew*et al* (2016) stated that the indicative values of the output per unit cultivated area for the BedeneAlemetena scheme was 58,940.242 birr/ha.And also Markos*et al.* (2019) reported that output per cropped area 125,027.3birr/ha. The value obtain in Ayserwm irrigation scheme was Mach greeter than the above research finding. This related to high value crop selection and crop productivity aspect. In the study area, farmers are cultivate high value crops (vegetable crops) and a large portion of the irrigated area was covered with high value cash crops garlic and Onion. This resulted for high output per unit-irrigated area.

B. Output per command area

This is the other land productive indictor to evaluate the productivity of the scheme from its design command area. The calculated value of output per command area of in the irrigation scheme was 457,538.2 birr/ha. Nuru*et al*, (2020) reported that the result of output per command area at Homacho and Jawis irrigation scheme are 38,692.8 and 19,730.86 birr /ha respectively. The calculated result was much greater than the above finding result. This indicates all the command areas are generating returns.

Generally the land productivity of scheme becomes high due to the increment of market of the production and the selection of crop.

II. Water productivity indicators

After measuring the discharge at various working irrigation scheme the average discharge was estimated to be 0.094 m^3/s. This discharge was used to estimate the amount of water diverted in this irrigation season. The irrigation season goes from November to March;the volumeofwater diverted in these months was0.094*130*24*60*60=1,055,808m^3/season. In this irrigation season the calculated value of crop water consumedwas1,335,289.6m^3.

C. Output per unit irrigation diverted

This is the water productivity indicator express by output per unit water and indicates how Mach water diverted for irrigation. The output per unit irrigation water diverted of 121birr/m^3were obtained from Ayserwm scheme.The result was much greater than the other finding result. This indicated that each volume of water was more productive. When land is limiting relative to water, output per unit land may be more important. Where water is a limiting factor to production, output per unit water may be more important (Molden et al, 1998).

D. Output per unit water consumed

This indicates that how Mach water consumed by crops and how well the total water consumed by crops is productive. The values for this indicator was found to be 96birr/m^3. The result shows that high value of output per water consumed. Generally, the value of water productivity indicators computed from Ayserwm shown good performance. This implies that, there was better crop selection experiences that leads to better water productivity.

4.2.2.2. Water use indicators

A. Relative water supply

This indicator showed that the availability of water in relation to crop water demand. It relates to the total volume of water applied (irrigation plus total rainfalls) to the volume of water required by the crops. The calculated values of RWS in the scheme was 0.79. According to Perez *et al* (2005), categorized ARWS (Annual Relative Water Supply) values ranging from 0.9 to 1.2 as adequate, from 1.2 to 1.8 as excessive and values from 1.8 to 2.5 as very excessive. The result show that there is irrigation water scarcity at study area, which is less than crop water requirement.

B. Relative irrigation supply

This indicator estimated that the ratio of the volume of irrigation water diverted to the net irrigation water requirement. Theobtainedvalue of the scheme was 0.88. According to Dejen *et al*. (2012), relative irrigation supply value over one suggest over supply, while the value less than one indicates shortage of irrigation water. The result indicated that there is shortage of irrigation water at in the study area. This occur due to the expansion of irrigated land without considering the amount of water should divert. The finding of this result much less than Abdu and Bekele (2007) reported that the value of RWS and RIS was 4.6 and 6.6 respectively.

4.2.2.3. Physical performance indicators

A. Irrigation Ratio

This indicator shows that the level of utilization of a given irrigable area in the particular production season. The obtained value of irrigation ratio of the scheme was 1.2. Which means that 100% of command area was irrigate and additional 57.45ha of the scheme was expands during the study period. This occur the farmers were more interested to produce using irrigation because they get better income by producing cash crops and better land productivity are the other contributing factor for the expansion. This factor encourage more farmers to come the area and irrigate lands by leasing or renting from local land owners.

B. Sustainability of irrigated area

The sustainability of irrigated area express about the command area under irrigation is contracting or expanding as compared to the initially irrigated area. The obtained sustainability value of the scheme was 2.9. According to Boss (1997) if the computed value was less than one shows that the irrigable area becomes contracted and the value greater than one the irrigated area becomes expanding. Therefor the study result shows that the irrigable area expanded, which indicates the current irrigable area is higher than the command area. This implies that the current irrigated area was increased due to interests coming from neighboring farmers to irrigate extra land addition to designed one andincreasing the interest of farmers using irrigation for their better life. This expansion of irrigable area indicates there is more sustainable of irrigation scheme. This result nearly similar to Hamusit irrigation scheme as reported by Shenkut (2015) which is 3.09. But the result greater than Ketar irrigation scheme reported by Dinka (2017) which is 1.26.

Table 4. 9: Basic parameters and computed values of IR and SIA

Scheme Name	command Area (ha)	initial irrigated Area (ha)	currently irrigated Area (ha)	IR (%)	SIA (%)
Ayserwm	280	115	337.45	1.2	2.9

4.3. **Assessment of Farmers Perceptions**

To assess farmer's perception about the scheme performance were conducted by household from the total users of 80beneficiary farmers with structured questionnaire Appendices (XXIII). The respondents were selected randomly from total beneficiary farmers at head; middle and tail reach of the scheme in the study area. According to the result of the survey, the male and female-headed households were 83.8% and 16.2% of the beneficiaries respectively. The age group about 86.2%, 8.8% and 5% of the beneficiary household heads age was in the range of 18-64, 65-70 and <18 years of age, respectively. Regarding to education level 70% of the beneficiary household heads have formal education and 30% of has notformal education.About 58.8% of the beneficiary households in the irrigation schemes were married.

- ✓ Planning and management

In Ayserwm scheme there is water user association committee (WUA) which was established in 2008 with seven male members. The committee leads irrigation beneficiary and organized for the purpose of water distribution, collection of irrigation water fees, system maintenance and conflict management. However, asI discussed with beneficiary farmers most of the water user associationin the scheme doesn't order all activities in good manner. Due to this reasonillegal water user were contribute unfair water distribution in the users. This become from poor communication of WUA and beneficiary farmers.

In the scheme, water allocation was rigid rotational program in water team by 'ketena' level. The WUA prepare the irrigation schedule by guess without any technical support from agricultural experts. These conditions create to some farmers over supplied water while others obtained under supply it did not considered the crop types and their crop water requirements.The survey result in table (4.10) from the total respondents 47.5, 42.5, 7.5 and 2.5 % of the respondent farmers said that the construction idea initiated by government, local people, DA and project staff, respectively. This indicates that there is no agreement on who was initiate planning and development of the scheme.

Table 4. 10: Response of household in the process of planning

Who initiate the idea of construction the scheme?	Frequency	Percent
Local people	34	42.5
DA	6	7.5
Project staff	2	2.5
Government	38	47.5
Total	80	100.0

Source: Survey result 2021

A. Water distribution

Both water user association and beneficiaries of the irrigation scheme without designed irrigation schedule manage the water distribution in the study area. From total respondents 53.8% of the respondents reported that how much to irrigate decides by water user association, 40% of the respondent states that how much to irrigate decides by irrigation users, 3.8%of the respondent states this decide byKeble agricultural expert and 2.5%of the respondent states that how much to irrigate decides byWoredaagricultural expert. The result shows that the WUAs committee allocates water by guess because of lack of technical capacity and technical support. Hence, WUAs are unable to undertake effective, reliable, and equitable water distribution.

Table 4. 11:Response of household on how much to irrigate

Who decides how much to irrigate?	Frequency	Percent
Water user association	43	53.8
Keble agricultural expert	3	3.8
Yours own	32	40.0
Woreda agricultural expert	2	2.5
Total	80	100.0

Source: Survey result 2021

The result in table (4.12) indicates that 45, 30, 20 and 5 % of the respondents said that the criteria to irrigate the crop is based on the schedule set by water user association, checking the soil near the roots, when it is dry and waiting until crop leaves wilt respectively.

Table 4. 12: Response of household on the criteria to irrigate the crop.

What are the criteria are of used to irrigate the crop?	Frequency	Percent
Waiting until crop leaves wilt	4	5.0
Checking the soil near the roots	24	30.0
When it is dry	16	20.0
Based on the schedule set by water user association	36	45
Total	80	100.0

Source: Survey result 2021

The result in table, (4.13) from the total respondents 83.8, 10 and 6.3 % of the respondent states that the main irrigation scheduling criteria were fixed time period, water supply availability and conditions of the plant respectively. This indicates that in Ayserwm scheme the majority of irrigation beneficiary use fixed time periods.

Table 4. 13: Main criteria used to scheduling irrigation

What are the criteria farmers used to Scheduling irrigation?	Frequency	Percent
Water supply availability	8	10.0
Fixed time periods	67	83.8
Condition of the plant	5	6.3
Total	80	100.0

Source: Survey result 2021

- ✓ Sustainability

During the planning and construction period the irrigation users participating a positive contribution to create sense of ownership and to assure sustainability. The government has been making huge investment in irrigation scheme design and construction within the participation of the community in the area. Thus leads to increasefarmer's sense of ownership and responsibility for operation and maintenance activities. In the study area, from the total respondents 67.5% of the respondents were participate that the maintenance activity of the irrigation scheme. This activity is one times a year clean canals by removing sediments and weeds. However, 32.5% of the respondent's states that they do not participate the maintenance activity. The reason of the respondents not participate the maintenance activities it is not their responsibility to participate in maintenance of the scheme and they do not know how to do it.

Table 4. 14:The respondent's response on the Participation of the irrigation scheme maintenance

Have you ever participated in Maintenance Of the irrigation scheme?	Frequency	Percent
Yes	54	67.5
No	26	32.5
Total	80	100.0

Source: Survey result 2021

In table (4.15) the result indicates that 76.3, 12.5,10 and 1.3% of the respondents side that the responsibility to keep the infrastructure from damage beneficiary of the scheme, Woreda administration, Keble administration and regional government respectively. This indicates large percent of the respondents states that keeping the scheme infrastructures from damageby the responsibility of beneficiary of the scheme.

Table4.15: The respondent's fed back from keepingthe scheme infrastructures from damage

Who is responsible to keep the infrastructures Of the scheme from damage?	Frequency	Percent
Regional government	1	1.3
Woreda administration	10	12.5
Keble administration	8	10.0
Beneficiary of the scheme	61	
76.3Total		80
100.0		

Source: Survey result 2021

D. Conflicts and conflict management

Conflict can occur between the beneficiaries at different reaches of the scheme. Most conflicts were happened among irrigation beneficiaries especially between head and tail users in the study area. The tile users does not get irrigation water the required amount and at require time by the cause of water theft,dissipate of irrigation water by upper users. This increase time to time so that water shortage was happened in tile usersthis leads to conflict. Conflict between farmers within the same irrigation blocks also occur mainly due to issues related to sharing of irrigation water and water theft. More frequent conflicts between farmers indicate lack of smooth communication between farmers and the water user committee.Result in table (4.16), shows that from the total respondents 77.5% of the respondent farmers said thatthere is conflict among water users due to the problem of water management and 22.5% of the respondent farmer's states that there is no conflict among water users.

Table 4. 16: The respondents’ response on conflict between users

Is there any conflict among water users?	Frequency	Percent
Yes	62	77.5
No	18	22.5
Total	80	100.0

Source: Survey result 2021

In table (4.17) from the total respondents 83.8%,13.8, and 2.5 % of the respondents farmers states that the main actors in conflict resolutions was done by water user association, Keble council, and social court, respectively.

Table 4. 17: Respondents answer on conflict resolution system

Who are the actors in conflict resolution?	Frequency	Percent
WUA	67	83.8
Keble council	11	13.8
Social courts	2	2.5
Total	80	100.0

Source: Survey result 2021

5. SUMMARY, CONCLUSTION AND RECOMMNDATION

5.1. Summary

This study was conducted to evaluate the performance of Ayserwm Medium Scale irrigation scheme and Farmers perception in Mojana Wedera Woreda, Amhara Regional State of Ethiopia using internal and external performance indicators established by IWMI. The internal performance indicators were computed as conveyance efficiency, application efficiency, deep percolation ratio, storage efficiency, distribution efficiency and overall efficiency and from the external indicators computed as agricultural, water use and physical performance indicators. Primary data taken from the field includes frequent field observation, determination of soil texture, bulk density, and moisture contents of the soils of the selected irrigation fields before and after irrigations, discharge measurements in the canals, measuring the depth of water applied to the farmers' field by using two inches parshall flumes and interviewing beneficiary farmers. While the secondary data collection include design document, total yields, irrigated area per crop per season, crop type, cropping pattern and climate data.

In this study the calculated value of conveyance efficiency at the main and secondary canals were 70.68% and 54.039% respectively, within the average value of conveyance efficiency of the scheme was 62.67%. The calculate value of application efficiency, deep percolation ratio, storage efficiency and distribution efficiency in the scheme were 58.18%, 41.84%, 63.18%and 85.42% respectively. The overall efficiency of the scheme was 36.27%. The agricultural indicators, which were output per unit irrigated area, output per command area, output per unit irrigation water diverted and output per unit water consumed were 379,643.5birr/ha, 457,538.2birr/ha,121 and 96birr/m3 respectively. The water use indicators which is relative water supply and relative irrigation supply in the scheme were 0.79 and 0.88 respectively. The physical performance indicators irrigation ratio and sustainability of irrigated area were 1.2 and 2.9 respectively. The perception of farmers about the scheme performance was asses by preparing sample questionnaires for household survey. The questionnaire focused on water management activity, irrigation scheduling, maintenance activity, and source of conflict and conflict management. The irrigation system was poorly managed in terms of water distribution, conflict management and communication between irrigators and water user association.

5.2. **Conclusions**

In this study, the main and secondary canal conveyance efficiency value obtained below the recommended range. This low value occur due to overflow of water on the canal, poor canal management and using of local water control gates. The application and storage efficiency value in the study area was sufficient. From the applied depth of water 41.84% was lost due to deep percolation this occur in the cause of over irrigation water application and poor water management. The overall efficiency of the scheme was 36.27%, which indicates poor performance. The result of agricultural indicators in the study area obtained large values. This large value obtained due to the selection of high value of crops. The relative water supply and relative irrigation supply in the scheme become less than one. Which indicates the amount of water applied during irrigation event was less than required by crops. The computed value of irrigation ratio and sustainable of irrigation area become greater than one. This indicates the irrigation scheme is more sustainable. However, the irrigation command area was expanding without considering water resource. This leads to the scheme insufficient irrigation water supply for crop production.

The irrigation water management in the scheme was poor this shows that there was the problem of water user association, not properly managed the scheme. This however can be improved by sharing experience from different irrigation scheme which has a good performance. In the absence of any schedule of irrigation water, it was common for farmers to divert high volume of water to their fields combined with poor knowledge about the crop water requirement of the farmers. The allocation of water was rigid rotational which was fixed time and it was not consider the irrigated area size of the users.Currentirrigatedarea is greater than designed command area and farmers in downstream are facing shortage of water. Due to this causes conflicts were happened, the solving mechanisms were poor. In general, based on the assessment carried out, it can be concluded that improvement measures should be taken to improve the performance of the scheme.

5.3. **Recommendations**

Based on the results, the following recommendations are forward to improve the performance of the scheme.

- ✓ The conveyance efficiency becomes low due to losses in the conveyance systemanduse of illegal diversion gates for irrigation water. It improved by repair the broken canals, continues cleaning of canals practices, install proper diversion gates and the amount of water divert from the source by considering of the cross section area of the canal it minimize overflow of water on the canals such type of activity will solve the problems.
- ✓ Beneficiary farmers in the study area participate in canal clearing and regular maintenance was one times a year it is not adequacy.The canal requires, continuous removal of deposition of silt, sedimentation, free from weed, constructing of soil water conservation structure across the canal and canal bank protection. Therefore, the agricultural expert, the scheme WUA and beneficiary farmers should be working together.
- ✓ Agriculture expertsgive formal trainings for beneficiary farmers are necessary to enhance the knowledge of farmers regarding on proper irrigation water management, irrigation scheduling, negative impact of excess water application to the crops and structure maintenance for future use. The irrigation users get awareness regarding these issues, the scheme performance become increased.
- ✓ Water user association of the scheme is not well organized. Therefore, reforming or giving training to them is essential for ensuring good water management, fair distribution of irrigation water, resolving conflicts among users in the irrigation scheme.
- ✓ Finally, this research isrecommend that comparing the performance level of the scheme to the other irrigation scheme by using comparative indicatorsfor the future researchers.

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APPENDIXS

Appendix 1: Average 40 years (1980-2020) monthly climatic data and ETo CROPWAT 8 output

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	4.6	19.5	55	206	9.2	21.1	3.88
February	6.0	20.4	52	221	8.4	21.2	4.25
March	7.1	20.9	53	211	7.9	21.5	4.40
April	7.6	20.7	59	183	7.3	20.7	4.13
May	7.1	21.4	56	173	8.4	21.9	4.32
June	6.8	21.7	55	170	6.6	18.8	3.99
July	8.2	18.5	77	125	4.7	16.1	2.97
August	8.2	18.0	79	110	5.3	17.4	3.06
September	6.7	18.5	70	115	6.4	19.1	3.41
October	3.8	18.6	58	128	8.4	21.4	3.71
November	2.8	18.8	56	156	9.6	21.8	3.72
December	3.2	18.8	54	179	9.4	20.8	3.67
Average	6.0	19.7	60	165	7.6	20.1	3.79

Appendix 2:Mean monthly rainfall and effective rainfall

months	Rainfall mm	Eff rainfall mm
January	17.6	17.1
February	18.4	17.9
March	41.7	38.9
April	53.4	48.8
May	43.0	40.0
June	55.1	50.2
July	307.6	155.8
August	286.0	153.6
September	92.9	79.1
October	17.9	17.4
November	5.3	5.3
December	3.6	3.6
Total	942.5	627.7

Appendix 3:Garlic growth stage, effective rainfall, crop water and irrigation water requirement during growing period

Months	Decades	Stages	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	2.60	26.0	2.8	23.2
Nov	2	Init	0.70	2.61	26.1	1.3	24.8
Nov	3	Deve	0.72	2.65	26.5	1.3	25.3
Dec	1	Deve	0.81	2.99	29.9	0.9	29.0
Dec	2	Deve	0.92	3.37	33.7	0.5	33.2
Dec	3	Mid	1.01	3.78	41.6	2.2	39.4
Jan	1	Mid	1.02	3.90	39.0	4.6	34.4
Jan	2	Mid	1.02	3.97	39.7	6.3	33.4
Jan	3	Late	1.02	4.08	44.9	6.2	38.7
Feb	1	Late	0.95	3.90	39.0	5.2	33.8
Feb	2	Late	0.85	3.59	35.9	5.0	30.9
Feb	3	Late	0.76	3.25	26.0	7.7	18.4
					408.5	43.9	364.6

Appendix 4:CROPWAT 8 output for garlic crop irrigation scheduling

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	NetIrr mm	Deficit mm	Loss mm	Gr. Irrmm	Flow l/s/ha
1 Nov	1	Init	0.0	0.87	87	35	16.9	0.0	0.0	24.1	2.79
6 Nov	6	Init	0.0	1.00	100	24	12.5	0.0	0.0	17.8	0.41
10 Nov	10	Init	0.0	1.00	100	20	11.0	0.0	0.0	15.7	0.45
15 Nov	15	Init	0.0	1.00	100	23	13.1	0.0	0.0	18.8	0.43
20 Nov	20	Init	0.0	1.00	100	22	13.1	0.0	0.0	18.8	0.43
25 Nov	25	Init	0.0	1.00	100	21	13.4	0.0	0.0	19.1	0.44
1 Dec	31	Dev	0.0	1.00	100	25	16.5	0.0	0.0	23.6	0.46
7 Dec	37	Dev	0.5	1.00	100	26	17.9	0.0	0.0	25.6	0.49
13 Dec	43	Dev	0.2	1.00	100	27	19.7	0.0	0.0	28.2	0.54
20 Dec	50	Dev	0.0	1.00	100	32	24.4	0.0	0.0	34.9	0.58
27 Dec	57	Mid	1.1	1.00	100	31	24.8	0.0	0.0	35.4	0.59
3 Jan	64	Mid	2.4	1.00	100	31	24.5	0.0	0.0	35.0	0.58
10 Jan	71	Mid	0.0	1.00	100	31	24.9	0.0	0.0	35.6	0.59
18 Jan	79	Mid	0.0	1.00	100	32	25.3	0.0	0.0	36.1	0.52
25 Jan	86	Mid	0.0	1.00	100	31	25.2	0.0	0.0	36.0	0.59
1 Feb	93	End	0.0	1.00	100	32	25.2	0.0	0.0	36.0	0.60
9 Feb	101	End	0.0	1.00	100	32	25.9	0.0	0.0	37.0	0.54
18 Feb	110	End	0.0	1.00	100	34	27.6	0.0	0.0	39.4	0.51
28 Feb	End	End	0.0	1.00	0	27					

Appendix 5:Onion growth stage, effective rainfall, crop water and irrigation water requirement during growing period.

Months	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	2.60	26.0	2.8	23.2
Nov	2	Init	0.70	2.61	26.1	1.3	24.8
Nov	3	Deve	0.75	2.76	27.6	1.3	26.4
Dec	1	Deve	0.83	3.06	30.6	0.9	29.7
Dec	2	Deve	0.91	3.35	33.5	0.5	33.0
Dec	3	Deve	1.00	3.74	41.2	2.2	38.9
Jan	1	Mid	1.07	4.08	40.8	4.6	36.3
Jan	2	Mid	1.08	4.18	41.8	6.3	35.6
Jan	3	Late	1.01	4.05	44.6	6.2	38.4
Feb	1	Late	0.85	3.51	10.5	1.6	7.9
					322.7	27.5	294.1

Appendix 6:CROPWAT 8 output for onion crop irrigation scheduling

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Nov	1	Init	0.0	0.87	87	35	16.8	0.0	0.0	24.0	2.78
6 Nov	6	Init	0.0	1.00	100	24	12.3	0.0	0.0	17.6	0.41
10 Nov	10	Init	0.0	1.00	100	21	10.9	0.0	0.0	15.6	0.45
15 Nov	15	Init	0.0	1.00	100	24	13.0	0.0	0.0	18.6	0.43
20 Nov	20	Init	0.0	1.00	100	23	13.0	0.0	0.0	18.6	0.43
25 Nov	25	Dev	0.0	1.00	100	23	13.8	0.0	0.0	19.7	0.46
1 Dec	31	Dev	0.0	1.00	100	27	17.0	0.0	0.0	24.3	0.47
7 Dec	37	Dev	0.5	1.00	100	27	18.2	0.0	0.0	26.0	0.50
13 Dec	43	Dev	0.2	1.00	100	29	19.7	0.0	0.0	28.2	0.54
19 Dec	49	Dev	0.0	1.00	100	29	20.6	0.0	0.0	29.4	0.57
25 Dec	55	Dev	0.0	1.00	100	29	21.7	0.0	0.0	31.0	0.60
1 Jan	62	Dev	0.0	1.00	100	33	26.3	0.0	0.0	37.5	0.62
8 Jan	69	Mid	0.0	1.00	100	30	24.1	0.0	0.0	34.5	0.57
15 Jan	76	Mid	0.0	1.00	100	32	25.8	0.0	0.0	36.9	0.61
22 Jan	83	Mid	0.0	1.00	100	32	25.8	0.0	0.0	36.8	0.61
29 Jan	90	End	0.0	1.00	100	31	25.2	0.0	0.0	36.0	0.60
3 Feb	End	End	2.7	1.00	100	16					

Appendix 7: Potato growth stage, effective rainfall, crop water and irrigation water requirement during growing period

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.50	1.86	18.6	2.8	15.8
Nov	2	Init	0.50	1.86	18.6	1.3	17.3
Nov	3	Deve	0.53	1.98	19.8	1.3	18.5
Dec	1	Deve	0.74	2.72	27.2	0.9	26.2
Dec	2	Deve	0.96	3.53	35.3	0.5	34.8
Dec	3	Mid	1.16	4.33	47.6	2.2	45.3
Jan	1	Mid	1.18	4.49	44.9	4.6	40.3
Jan	2	Mid	1.18	4.57	45.7	6.3	39.5
Jan	3	Mid	1.18	4.71	51.8	6.2	45.7
Feb	1	Late	1.17	4.84	48.4	5.2	43.1
Feb	2	Late	1.08	4.57	45.7	5.0	40.7
Feb	3	Late	0.96	4.11	32.9	7.7	25.2
Mar	1	Late	0.84	3.63	36.3	11.0	25.4
					472.7	54.8	417.9

Appendix 8: CROPWAT 8 output for potato crop irrigation scheduling

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
2 Nov	2	Init	0.0	1.00	100	41	26.5	0.0	0.0	37.9	2.19
18 Nov	18	Init	0.0	1.00	100	40	30.0	0.0	0.0	42.8	0.31
4 Dec	34	Dev	0.0	1.00	100	42	35.5	0.0	0.0	50.8	0.37
16 Dec	46	Dev	0.0	1.00	100	43	38.9	0.0	0.0	55.6	0.54
26 Dec	56	Mid	0.0	1.00	100	42	40.1	0.0	0.0	57.3	0.66
5 Jan	66	Mid	0.0	1.00	100	43	41.7	0.0	0.0	59.6	0.69
15 Jan	76	Mid	0.0	1.00	100	41	39.7	0.0	0.0	56.7	0.66
25 Jan	86	Mid	0.0	1.00	100	42	40.0	0.0	0.0	57.2	0.66
4 Feb	96	Mid	0.0	1.00	100	44	41.8	0.0	0.0	59.7	0.69
15 Feb	107	End	0.0	1.00	100	49	46.6	0.0	0.0	66.6	0.70
10 Mar	End	End	0.0	1.00	0	69					

Appendix 9: Cabbage growth stage, effective rainfall, crop water and irrigation water requirement during growing period.

Months	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	2.60	26.0	2.8	23.2
Nov	2	Init	0.70	2.61	26.1	1.3	24.8
Nov	3	Init	0.70	2.59	25.9	1.3	24.7
Dec	1	Init	0.70	2.58	25.8	0.9	24.9
Dec	2	Deve	0.75	2.75	27.5	0.5	27.0
Dec	3	Deve	0.85	3.18	34.9	2.2	32.7
Jan	1	Deve	0.95	3.61	36.1	4.6	31.6
Jan	2	Mid	1.04	4.04	40.4	6.3	34.2
Jan	3	Mid	1.08	4.30	47.3	6.2	41.2
Feb	1	Mid	1.08	4.43	44.3	5.2	39.1
Feb	2	Mid	1.08	4.56	45.6	5.0	40.6
Feb	3	Late	1.07	4.57	36.6	7.7	28.9
Mar	1	Late	1.02	4.43	44.3	11.0	33.4
Mar	2	Late	0.98	4.32	21.6	6.7	14.8
					482.6	61.6	421.0

Appendix 10: CROPWAT 8 output for cabbage crop irrigation scheduling.

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Nov	1	Init	0.0	1.00	100	48	38.9	0.0	0.0	55.5	6.43
17 Nov	17	Init	0.6	1.00	100	46	41.9	0.0	0.0	59.9	0.43
4 Dec	34	Init	0.0	1.00	100	47	47.0	0.0	0.0	67.1	0.46
21 Dec	51	Dev	0.0	1.00	100	45	49.9	0.0	0.0	71.3	0.49
7 Jan	68	Dev	2.4	1.00	100	45	54.7	0.0	0.0	78.2	0.53
24 Jan	85	Mid	0.0	1.00	100	48	61.8	0.0	0.0	88.4	0.60
9 Feb	101	Mid	0.0	1.00	100	48	61.5	0.0	0.0	87.8	0.64
24 Feb	116	End	0.0	1.00	100	46	59.2	0.0	0.0	84.6	0.65
15 Mar	End	End	0.0	1.00	0	45					

Appendix 11:Tomato growth stage, effective rainfall, crop water and irrigation water requirement during growing period

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.60	2.23	22.3	2.8	19.5
Nov	2	Init	0.60	2.23	22.3	1.3	21.0
Nov	3	Init	0.60	2.22	22.2	1.3	21.0
Dec	1	Deve	0.68	2.50	25.0	0.9	24.1
Dec	2	Deve	0.82	3.02	30.2	0.5	29.7
Dec	3	Deve	0.98	3.65	40.1	2.2	37.9
Jan	1	Mid	1.13	4.29	42.9	4.6	38.3
Jan	2	Mid	1.18	4.58	45.8	6.3	39.5
Jan	3	Mid	1.18	4.72	51.9	6.2	45.7
Feb	1	Mid	1.18	4.86	48.6	5.2	43.3
Feb	2	Mid	1.18	5.00	50.0	5.0	45.0
Feb	3	Late	1.16	4.96	39.7	7.7	32.0
Mar	1	Late	1.05	4.58	45.8	11.0	34.8
Mar	2	Late	0.94	4.11	41.1	13.5	27.7
Mar	3	Late	0.85	3.65	18.2	6.5	11.0
					546.1	74.9	470.6

Appendix 12:CROPWAT 8 output for tomato crop irrigation scheduling

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Nov	1	Init	0.0	0.86	86	42	34.2	0.0	0.0	48.8	5.65
14 Nov	14	Init	0.0	1.00	100	33	29.2	0.0	0.0	41.7	0.37
27 Nov	27	Init	0.6	1.00	100	31	30.7	0.0	0.0	43.9	0.39
11 Dec	41	Dev	0.0	1.00	100	35	37.7	0.0	0.0	53.8	0.45
24 Dec	54	Dev	0.0	1.00	100	37	43.7	0.0	0.0	62.5	0.56
6 Jan	67	Dev	0.0	1.00	100	41	51.4	0.0	0.0	73.4	0.65
19 Jan	80	Mid	0.0	1.00	100	41	51.9	0.0	0.0	74.1	0.66
1 Feb	93	Mid	0.0	1.00	100	43	54.9	0.0	0.0	78.5	0.70
14 Feb	106	Mid	0.0	1.00	100	44	55.8	0.0	0.0	79.7	0.71
26 Feb	118	End	0.0	1.00	100	42	53.2	0.0	0.0	76.0	0.73
16 Mar	136	End	0.0	1.00	100	48	61.6	0.0	0.0	87.9	0.57
25 Mar	End	End	0.0	1.00	0	18					

Appendix 13:Carrot growth stage, effective rainfall, crop water and irrigation water requirement during growing period.

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	2.60	26.0	2.8	23.2
Nov	2	Init	0.70	2.61	26.1	1.3	24.8
Nov	3	Deve	0.77	2.85	28.5	1.3	27.2
Dec	1	Deve	0.89	3.29	32.9	0.9	32.0
Dec	2	Deve	1.02	3.72	37.2	0.5	36.7
Dec	3	Mid	1.07	4.01	44.1	2.2	41.8
Jan	1	Mid	1.07	4.08	40.8	4.6	36.3
Jan	2	Mid	1.07	4.16	41.6	6.3	35.4
Jan	3	Mid	1.07	4.29	47.2	6.2	41.0
Feb	1	Mid	1.07	4.42	44.2	5.2	38.9
Feb	2	Mid	1.07	4.54	45.4	5.0	40.4
Feb	3	Mid	1.07	4.60	36.8	7.7	29.2
Mar	1	Mid	1.07	4.66	46.6	11.0	35.6
Mar	2	Late	1.04	4.59	45.9	13.5	32.4
Mar	3	Late	0.99	4.27	42.7	13.1	28.3
					586.0	81.4	503.2

Appendix 14: CROPWAT 8 output for carrot crop irrigation scheduling

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
4 Nov	4	Init	0.0	1.00	100	46	38.4	0.0	0.0	54.8	1.59
21 Nov	21	Dev	0.0	1.00	100	48	47.7	0.0	0.0	68.1	0.46
6 Dec	36	Dev	0.0	1.00	100	43	48.8	0.0	0.0	69.7	0.54
18 Dec	48	Dev	0.0	1.00	100	37	46.1	0.0	0.0	65.9	0.64
30 Dec	60	Mid	0.0	1.00	100	36	45.5	0.0	0.0	65.0	0.63
12 Jan	73	Mid	0.0	1.00	100	38	48.5	0.0	0.0	69.2	0.62
25 Jan	86	Mid	0.0	1.00	100	38	48.3	0.0	0.0	69.0	0.61
6 Feb	98	Mid	0.0	1.00	100	36	46.4	0.0	0.0	66.3	0.64
18 Feb	110	Mid	0.0	1.00	100	38	48.9	0.0	0.0	69.9	0.67
2 Mar	122	Mid	0.0	1.00	100	37	47.2	0.0	0.0	67.4	0.65
15 Mar	135	End	0.0	1.00	100	37	47.2	0.0	0.0	67.4	0.60
30 Mar	End	End	0.0	1.00	0	32					

Appendix 15:Soil infiltration rate in Ayserawm irrigation scheme.

Cumulativetime (min)	Elapsedtime (min)	Readingbeforefilling (cm)	Readingafter filling (cm)	Incremental infiltration (cm)	Infiltrate rate (cm/mi)	Infiltrate rate (cm/h)	Cumulativeinfiltraterate(cm)
0	0	0	13	0	0	0	0
0.5	0.5	9.97	13	3.03	6.06	363.6	3.03
1	0.5	10.18	13	2.82	5.64	338.4	5.85
3	2	10.2	13	2.8	1.4	84	8.65
5	2	10.27	13	2.73	1.365	81.9	11.38
10	5	10.82	13	2.18	0.436	26.16	13.56
15	5	11.14	13	1.86	0.372	22.32	15.42
20	5	11.26	13	1.76	0.152	9.12	17.18
30	10	11.51	13	1.49	0.149	8.94	18.67
50	20	11.67	13	1.33	0.0665	3.99	20
70	20	11.83	13	1.17	0.0585	3.51	21.17
100	30	12.02	13	0.98	0.033	1.98	22.15
130	30	12.56	13	0.44	0.014	0.84	22.59
160	30	12.62	13	0.38	0.012	0.72	22.97
190	30	12.68	13	0.32	0.011	0.7	23.29
220	30	12.68	13	0.32	0.011	0.7	23.61
250	30	12.68		0.32	0.011	0.7	23.93

Appendix 16: Main canal conveyance efficiency and losses

observation point (m)	Qin(l/s)	Qout (l/s)	Ec(%)	Ec/100m	Wl(%)	Wl(ls-1 100m-1)
(0-400)	167.52	160.18	95.62	23.90	4.38	1.83
(400-800)	134.18	66.48	49.54	12.39	50.46	16.93
(800-1300)	66.48	46.75	70.32	14.06	29.68	3.95
(1300-1600)	46.75	39.09	83.62	27.87	16.38	2.55
(1600-2200)	39.52	30.83	78.00	13.00	22.00	1.45

(2200-3000)	30.83	20.40	66.18	8.27	33.82	1.30
(3000-3600)	20.40	10.50	51.47	8.58	48.53	1.65
Average			70.68		29.32	4.24

Appendix 17:Secondary canal conveyance efficiency and losses

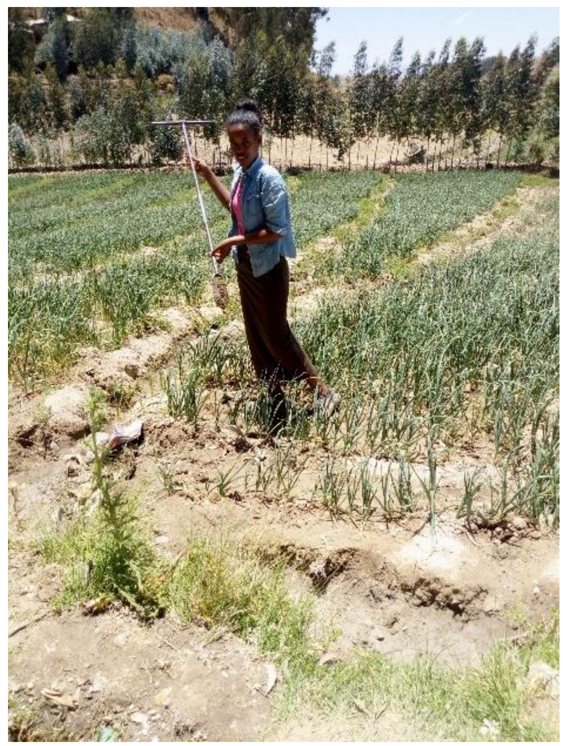
observation point (m)	Qin(l/s)	Q out (l/s)	Ec(%)	Ec%/100m	Wl(%)	Wl(ls-1 100m-1)
0-200	85.28	54.22	63.58	31.79	36.42	15.53
200-600	54.17	39.10	72.18	18.04	27.82	3.77
600-1450	39.08	22.16	56.71	6.67	43.29	1.99
0-540	89.13	30.77	34.52	6.39	65.48	10.81
0-470	75.87	32.79	43.22	9.60	56.78	9.57
Average			54.04		45.96	8.33

Appendix 18: Application and storage efficiencies

Canal reach	Applied depth(mm)	Stored depth(mm)	Required depth (mm)	Ea (%)	Es (%)
Head	58.98	38.72	50.96	65.64	75.98
Middle	47.93	25.61	45.73	53.43	56.003
Tile	43.12	23.90	41.51	55.42	57.58
Average				58.16	63.19

Appendix 19: Free flow discharge values for different size of parshal flumes

Throat width b_c in feet or inches	Discharge range in $m^3/s \times 10^{-3}$		Equation $Q = K h_a^u$ (Q in m^3/s)	Head range in metres		Modular limit h_b/h_a
	minimum	maximum		minimum	maximum	
1″	0.09	5.4	$0.0604\ h_a^{1.55}$	0.015	0.21	0.50
2″	0.18	13.2	$0.1207\ h_a^{1.55}$	0.015	0.24	0.50
3″	0.77	32.1	$0.1771\ h_a^{1.55}$	0.03	0.33	0.50
6″	1.50	111	$0.3812\ h_a^{1.58}$	0.03	0.45	0.60
9″	2.50	251	$0.5354\ h_a^{1.53}$	0.03	0.61	0.60
1′	3.32	457	$0.6909\ h_a^{1.522}$	0.03	0.76	0.70
1′6″	4.80	695	$1.056\ h_a^{1.538}$	0.03	0.76	0.70
2′	12.1	937	$1.428\ h_a^{1.550}$	0.046	0.76	0.70
3′	17.6	1427	$2.184\ h_a^{1.566}$	0.046	0.76	0.70
4′	35.8	1923	$2.953\ h_a^{1.578}$	0.06	0.76	0.70
5′	44.1	2424	$3.732\ h_a^{1.587}$	0.06	0.76	0.70
6′	74.1	2929	$4.519\ h_a^{1.595}$	0.076	0.76	0.70
7′	85.8	3438	$5.312\ h_a^{1.601}$	0.076	0.76	0.70
8′	97.2	3949	$6.112\ h_a^{1.607}$	0.076	0.76	0.70



Appendix 20:soil sample for bulk density and soil water determination


Appendix 21*: Household surveyand agricultural expert interview*


Appendix 22:Mismanagement of secondary canal and seepage problem in the main canal

Appendix 23:Double ring infiltrometer and parshall flume

Appendix 24: **Questionnaires**

Survey questionnaires used to collect household level data on Ayserawm MSI scheme performance. This questionnaire is being administered for research/academic purpose. The information was used to evaluate the performance of Ayserawm Medium Scale Irrigation (MSI) schemein North Shewa of Amhara Region, Ethiopia.

Dear Respondents

My Name Is Habtam Getie Negash from Hawassa University, Ethiopia. I am conducting a study on the performance evaluation of Ayserawm Medium scale irrigation scheme. Therefore, I am kindly requesting you to give a response as much as you can.

SECTION I: HOUSEHOLD CHARACTERISTICS

1. Name of the Respondent__________________________________ Kebele ___________
2. Sex of the respondent: 1= Male 2 = Female
3. Family Size

No	Name of members of HHs	Sex		Age of HHs			
		M	F	<18	18-64	65-70	>71
1							
2							
3							
4							
5							
6							
Total							

4. Do you have any formal education? A. Yes B. No
5. If your answer is yes, what is level of your education? A. Elementary B. Secondary school C. High school D. College and above
6. Marital status of the respondent: A. Single B. Married C. Divorced D. Widow
7. What is your main occupation? A. Agriculture B. Trading/Commerce
   C. Artisan/Carpentry D. public Service E. Others, specify
8. How many experience of farming in years.........?
9. Do you have irrigation farm? A. Yes B. No

10. If yes, where is the location of your irrigation farm? A. head (upper) B. Middle part C. tail

11. What are the major crops you produce by irrigation? ---

    ----

12. The yield per hectare that you gain from the irrigation farm--------------

SECTION II: DATA ON AYSERAWM SMALL SCALE WATER DISTRIBUTION

1. Is there equitable distribution of irrigation water among all beneficiaries?

   A.Yes B. No

2. If no, what are the causes for the unequal water distribution?

   A. Water scarcity B. unequal water distribution C. sedimentation problem

   D. Over abstraction of water by upstream users E.Damaged control structures (at intake)

   F. Others

3. Is the distribution fair? A. Fair B. Unfair

4. If unfair, why is it so (explain);

   A. Head users Corrupted officials/WUA B. illegal water users

   C. Non-reliability of the water sources D. Others explain

5. Do you irrigate all of your irrigable land? A. yes B. No

6. If not, why? Rank in order; A. Shortage of water B. Low productivity

   C. Getting sufficient produce by rain feed agriculture E. poor maintenance

SECTION III: IRRIGATION WATER ADMINISTRATION

1**.**Who decides how much to irrigate?

A. Water user association B. Keble administration C. yours own D. Wereda administrations

2.What are the criteria of used to irrigate the crop?

A. Waiting until crop leaves wilt B. checking the soil near the roots C. when it is dry

D. Irrigate every day E. Based on the schedule set by water user association

3. How many times you produce annually by applying irrigation ….. When…...............?

SECTION IV: DATA ON AYSERAWM SMALL SCALE STRUCTURE AND COUSE TO PROBLEM OF PERFORMANCE

1. Who initiate the idea of constructing the structures?

   A. Local people B. DA C. Project staff D. Government E. Others specify

2. If it is not the local people, have you agreed about the construction of the structures?

   A. Yes B. No Why? ....

3. Did you agree on the project/diversion site? A. Yes B. No
4. If no, what was your opinion about the site of the diversion? ……………………
5. Did you face any problem because of the site selection?

   A. Yes B. No

6. If yes, what was the problem? ---
7. Do you think the project is important in your area? A. Yes B. No
8. If yes, has the use of irrigation increased your annual income? A. Yes B. No
9. If yes, what is the estimated proportion of increment in the amount of income from crops? Compared to before the project time …………….? %
10. Explain the type of contribution you made for the project during construction?

    A. Money, (Amount, birr/year ……………) B. labor C. material D. Land

    E. other (specify)

11. Do you see any structural failure? A. Yes B. No
12. If yes, which structures?

    A. The head work B. The canals C. Other structures (indicate)

13. The cause of failure of structure? A. design problem B. site selection

    C. problem of construction material D. un properly construction of the structure

E. other (specify)

14. Have you ever participated in maintenance of the irrigation scheme?

A. Yes B. No

15. If you do not make the maintenance, what is the reason?

A. It is not my responsibility B. I do not know how to do it C. Others (specify) __

16. Who is responsible to keep the infrastructures of the scheme from damage?

A. Federal government B. Regional government C. Zone administration

D. Wereda administration E. Kebele administration F. Beneficiary of the scheme

17. Are there any problems during the application of irrigation water? A. yes B. No

18. If yes, what are they? (Rank them)

A. Downstream conflict B. Shorter time allowed for irrigation water flow

C. Water use administration problem D. Lack of maintenance

E. Lack of operational skill/training F. Others…

19. Do you feel that the irrigation scheme belongs to you?

A. Yes B. No

20. If No, whom do you think it belongs to?

A. to the community B. to the government C. to the NGOs

D. any combination of the above

21. Is there any conflict among water users? A. Yes B. No

22. if yes, what are the causes for conflict?

A. Water shortage B. Water theft C. Uneven distribution of water D. Others, specify

23. Who are the actors in conflict resolution? A. WUA B. Kebele council C.social courts

D. other

24. Do you have access to different input supply for irrigation?

A. Yes B. No

25. What are the main constraints for production and productivity?

A. Water shortage B. Land shortage C. Insufficient input supply for irrigation D. poor access to market E. un availability of high-quality seed F. Other (specify)……………….

26. Is there a mechanism of water pricing for irrigation users? A. Yes B. No

27. If yes, in what way do you price?

28. What are the criteria farmers used to scheduling irrigation? (Rank in order according to the priority)

A. Water supply availability B. Fixed time periods C. Condition of the plant D. Other specify