COMPARATIVE PERFORMANCE ASSESSMENT OF MOJO ASHA AND ADANO SMALL SCALE IRRIGATION SCHEMES IN EAST HARARGHE ZONE, OROMIA REGION

MSc THESIS

EBSA MUSTEFA HAKIM

OCTOBER, 2017

HAWASSA, ETHIOPIA

# COMPARATIVE PERFORMANCE ASSESSMENT OF MOJO ASHA AND ADANO SMALL SCALE IRRIGATION SCHEMES IN EAST HARARGHE ZONE,OROMIA REGION

EBSA MUSTEFA HAKEM

A THESIS SUBMITTED TO THE SCHOOL OF
WATER RESOURCES ENGINEERING, INISTITUTE OF TECHNOLOGY, SCHOOL
OF GRADUATE STUDIES, HAWASSA UNIVERSITY

IN PARTIAL FULFILMENT OF THE REQUIRMENTS
FOR THE DEGREE OF MASTER OF SCIENCE IN IRRIGATION AND
DRAINAGE ENGINEERING

OCTOBER, 2017
HAWASSA, ETHIOPIA

## DECLARATION AND COPYRIGHT

I, Ebsa Mustefa Hakem, declare this M.Sc thesis is my own original work and that it has not been presented to any other University, and all sources of material used in this thesis have been duly acknowledged.

Name: Ebsa Mustefa Hakem

Signature: ________________

Date:____________________

## ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled" COMPARATIVE PERFORMANCE ASSESSMENT OF MOJO ASHA AND ADANO SMALL SCALE IRRIGATION SCHEMES IN EAST HARARGHE ZONE, OROMIA REGION" submitted in partial fulfillment of the requirements for the degree of master of science in IRRIGATION AND DRAINAGE ENGINEERING, the graduate program of the School of Water Resources Engineering, Institute of Technology, School of Graduate Studies, Hawassa University and has been carried out by Ebsa Mustefa Hakem, Id. No PGIDE/009/08, under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the school.

Sirak Tekleab (PhD): ________________ _____________

Major Advisor Signature Date

Moltot Zewdie (PhD): ________________ _____________

Co- Advisor: Signature Date

**ACKNOWLEGEMENTS**

First and foremost, I would like to thank my Almighty ALLAH who gave me health and passed every difficult situation during study and my life at all.

My deepest indebted gratitude goes to my instructor and advisor Dr. Sirak Tekleab for his devotion of precious time, valuable suggestions and comments. I enjoyed your systematic guidance from the early design of the proposal to the final write up of this thesis and materials you have took on different courses which helped me a lot to apply the acquired knowledge for this thesis. I really, appreciate your kindness. My gratitude also goes to my instructor and Co-advisor Dr. Moltot Zewdie his kind support and encouragement give me strength right from the start to the last of the research work.

I would like to gratefully thank the Ministry of Water, Irrigation and electricity and Meyu Muluke Woreda for giving me the opportunity to learn M.sc program and Haramaya University Institute of Technology (HUTI) for providing me the research materials to conduct tests in their soil laboratory. My gratitude also goes to Oromia Irrigation Development authority office and East Hararghe Branch and Irrigation Development authority office of Girawa district for given data for my study.

I would like to extend my thanks to Oromia Irrigation Development authority office expert Elias Abdi and East Hararghe Oromia Irrigation Development authority office branch manager Abdi Abdulkadir for your given data related to my research and also Girawa district Irrigation Development Department expert Yahaya Ahmad and Durresa Ugaas for your kind co-operation during field work.

I feel very grateful thanks to my father Mustefa Hakem and my mother Abida Mummad for their patience and encouragement throughout the research period and my life at all. And also I feel great pleasure to express my special gratitude to my wife Feiza Mohammed. I have no words to appreciate for her moral support and patience.

Last but not least, I would like to thank all of my instructors for giving me all the basic science and Hawassa University Institute of Technology.

# DEDICATION

I dedicate this thesis to my father Mustefa Hakem and my mother Abida Mummad.

## LIST OF SYMBOLS

| Symbol | Description | Dimension |
|---|---|---|
| $ET_c$ | Crop evapotranspiration | $(LT^{-1})$ |
| $ET_o$ | Potential evapotranspiration | $(LT^{-1})$ |
| $(e_a-e_s)$ | Vapour pressure deficit for measurement at 2 m height | (k Pa) |
| G | Soil heat flux | $(MJ\ m^{-2}\ d\text{-}^{1})$ |
| $K_c$ | Crop coefficient | (-) |
| R | Net radiation at crop surface | $(MJ\ m^{-2}\ d\text{-}^{1})$ |
| T | Air temperature at 2 m height | (°C) |
| U | Wind speed measured at 2 m height | $(m\ s^{-1})$ |
| $\Delta$ | Slope of vapour pressure curve | $(k\ pa°C^{-1})$ |
| Y | Psychrometric constant | $(k\ pa°C^{-1})$ |
| $\rho_b$ | Dry bulk density | $(g/cm^3)$ |
| $\theta_{AI}$ | Moisture content after irrigation | (mm) |
| $\theta_{BI}$ | Moisture content before irrigation | (mm) |
| $\theta_{FC}$ | Moisture content at field capacity | (%) |
| $\theta_{PWP}$ | Moisture content at permanent wilting point | (%) |
| $\theta_V$ | Volumetric moisture content | (%) |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AMS | Actual Moisture Storage |
| a.s.l | Above sea level |
| CWR | Crop Water Requirement |
| DA | Development Agent |
| E | East |
| $E_a$ | Field application efficiency |
| $E_c$ | Conveyance efficiency |
| E.C | Ethiopian Calendar |
| ETo | Reference evapotranspiration |
| FAO | Food and Agricultural Organization |
| FDRE | Federal Democratic Republic of Ethiopia |
| G.C | Gregorian Calendar |
| GDP | Grows Domestic Production |
| GPS | Geographical positioning system |
| ha | Hectares |
| hrs | Hours |
| IFAD | International Food Aids Development |
| IWMI | International Water Management Institute |
| IWR | Irrigation Water Requirement |
| Kg | Kilogram |
| Km | Kilometer |
| km/day | Kilometer per hour |
| m | Meter |
| mm | Millimeter |
| $m^3$ | Cubic meter |
| MC | Main Canal |
| Max | Maximum |
| Min | Minimum |
| MJ | Mega joule |

| | |
|---|---|
| MOWR | Minister of Water Resource |
| N | North |
| NGO | Non Government Organization |
| O&M | Operations and Maintenances |
| OIDA | Oromia Irrigation Development Authority |
| OPUIA | Output per Unit Irrigated Area |
| OPUIS | Output per unit Irrigation Supply |
| OPUWS | Output per Unit Water Supply |
| RF | Rain Fall |
| RH | Relative Humidity |
| RIS | Relative Irrigation Supply |
| RPIP | Research Program on Irrigation Performance |
| RWS | Relative water Supply |
| SC | Secondary Canal |
| SCS | Soil Conservation Service |
| SMD | Soil Moisture Deficit |
| TAW | Total Available Water |
| USDA | United State Development Agency |
| WAD | Water Applied Depth |
| WEMRO | Water Energy and Mineral Resource Office |
| WUA | Water Users Association |
| $Z_r$ | Depth of water in root zone (mm) |

**TABLE OF CONTENTS**

## LIST OF TABLE



## LIST OF FIGURE

## LIST OF ANNEX TABLE

## LIST OF ANNEX FIGURE

## ABSTRACT

This study attempts to assess and cross-compare the performance of two small-scale irrigation schemes found in Oromia regional state namely, Mojo Asha and Adano irrigation schemes using comparative indicators. After collection of the valuable data from various sources, data analysis techniques were implemented for evaluating their performance using selected performance indicators such as conveyance efficiency, Application efficiency, system efficiency, water productivity and land productivity. The results showed that the average conveyance efficiencies of the two schemes were 83.41 % and 76.78 % at Mojo Asha and Adano respectively. It was lower at Adano than Mojo Asha scheme due to poor water management and irrigation structures' deterioration. The maximum value of application efficiency found in downstream field of Mojo Asha scheme were 65.43 % and the minimum value was found in the Adano scheme at upstream field 40.45 % due to much amount of water was applied to the field without considering water requirement. The results of water use performance also indicated that the ratio of annual relative water supply were1.09 and 1.19 at Mojo Aasha and Adano schemes respectively, and ratio of annual relative irrigation supply were 1.12 and 1.27 at Mojo Aasha and Adano schemes respectively. The result indicated that water distribution is not tightly related to crop water demand or applying more than the demand. From analysis of agricultural performance the output results showed that the outputs per unit irrigation supply were 8.62 and 7.92 Birr/$m^3$ at Mojo Asha and Adano schemes respectively. Whereas output per unit irrigation delivered were 10.78 and 9.70 Birr/ $m^3$ at Mojo Asha and Adano schemes respectively. Outputs per unit command area in Birr/ha were 82501 and 96750 at Mojo Asha and Adano scheme respectively. Outputs per unit irrigated cropped area in Birr/ha were 55237 and 56437.5 at Mojo Asha and Adano schemes respectively. In case of water productivity Mojo Asha scheme was performing better than Adano scheme due to more productive use of irrigation water while land productivity was performing better at Adano than Mojo Asha scheme due to more intensive irrigation and better investment. Generally evaluation results of different indicators give information of performance level of the schemes that enables to transfer best practice to propose improvement measures.


*Key words: Comparative, Performance, Water use efficiency, Land and Water productivity.*

# 1 INTRODUCTION

## 1.1 Background

Growth of the world population and the demand for food will continue in the foreseeable future. For this reason one of the world's great challenges is to increase food production in a sustainable manner so that a rapidly growing global population can be fed. Global estimates indicate that irrigated agriculture produces nearly 40% of food and agriculture commodities on 17% of agricultural land (FAO, 1997). At present in Africa, about 12.2 million hectares benefit from irrigation, which is equal to only about 8.5% of the cultivated land. In sub Saharan Africa, only about 10% of the agricultural production comes from irrigated land (FAO, 1997).

Ethiopia is one of the sub-Sahara African countries characterized by low standard of living and widespread poverty. The incidence of poverty stands at 44 % at the national level (FAO, 2006). Currently, about fifteen million people are facing food insecurity, either chronic or transitory in nature. About five to six million people are chronically food insecure every year (FAO, 2006). There are people who do not have the capacity to produce or buy enough food to meet their annual food needs even under normal weather and market conditions. The remaining ten million are vulnerable, with a weak resilience to any shock. Under any emergency circumstances, the likelihood of these people falling back into food insecurity is high (FAO, 2006). In order to address food insecurity of the rapidly growing population in Ethiopia, the current agricultural area assumed to increase by 25%, while average yields are assumed to increase by one-half by 2020 (Ehui et al., 2002).

The most of population in Ethiopia lives in highland areas and dependent on agriculture with a low level of productivity (MoA, 2011). Agriculture is a mainstay of Ethiopian economy (World Bank, 2006; Makombe et al., 2011). According to FDRE (2010) report agriculture to contribute almost 41% of the gross domestic product (GDP); 90% of the foreign exchange earnings and employs, almost 85% of the total population living in rural area depend on agricultural sector.

The challenge that Ethiopia faces in terms of enhancing food security is associated with both inadequate food production even during good rain years due to management problems and natural failures due to erratic rainfall. However, the country has not done much in developing irrigated agriculture to overcome the problems of food insecurity and extreme rural poverty, as well as to create economic dynamism in the country (Awulachew et al., 2007). Out of the total potential irrigable area (about 4.5 million hectare), only 6% is in use (Tilahun and Paulos, 2004). Recently, the Ethiopian government, appreciating the contribution of irrigation to household income and food security, initiated irrigation development program for the period of 2005-2016 with a target of developing 276,612 hectare, which brings the total area under irrigation in the country to 471,862 hectares where development of small-scale irrigation is given a priority (MoWR, 2002).

To overcome the recurrent drought problem and to achieve food self-sufficiency, the government and non-governmental organizations, private institutions have been implementing small-scale irrigation projects in different regions of the country (Hundie, 2006). Therefore, one means by which agricultural production can be increased to meet the growing food demands is through increasing agricultural yield and increasing cropping intensity (number of crops per year). Increasing yields in both rain-fed and irrigated agriculture and cropping intensity in irrigated areas through various methods and technologies are the most viable options for achieving food security in Ethiopia (Mekuria, 2003).

Oromia is one of the nine regional states in the country with its surface area of 359,620 $km^2$, constituting about one third of the total area of the country. According to the study conducted by the Oromia Irrigation Development Office (OIDA, 2013), the land suitable for surface irrigation in Oromia is estimated to be 1.7 million hectares of which only 390,000 ha (23%) has been developed so far. Out of these developed areas, 23% are under traditional irrigation, 19% under modern irrigation and 58% developed by micro irrigation of less than 2.5Ha.

According to the data from Eastern Hararghe Zone WEMRO, the small-scale irrigation development in the Zone from 1993/4-2002/3 E.C was 58 projects, of which 18 are not functional, 8 under construction and 32 are functional with no indication of its sustainability (Elias, 2011). Out of these irrigation five schemes are found in Girawa Woreda where Mojo Asha and Adano small scale irrigation schemes are counted among them.

This study was attempted to assess and compare performance of these schemes in a number of settings to understand where the system stands with respect to productive utilization of land and water, to compare relative performance of schemes.

## 1.2 Statement of Problems

Rapid growth of small-scale irrigation constitutes a major requirement for the agricultural development and food security strategies in the country. Therefore, government and non government organizations are focusing in constructing irrigation project in different regions of the country to achieve food self sufficiency. However there is wide spread low level with the performance of irrigation schemes in Ethiopia. The picture for Ethiopia is more severe and serious as the country's food production per capital is below the average for Sub-Saharan African countries. Despite its dominance, the performance of the agricultural sector has been disappointing in Ethiopia (Rose, 1993).

The performances of most irrigation schemes in Ethiopia are below expectation due to reasons related to management, operation and maintenance of the system (Hundie 2006). The performance evaluation of the schemes is not common in the country rather than developing new schemes. This problem is more aggravated when it comes to community based small scale irrigation projects. In Ethiopia, scheme performance is estimates on average 36% below design capacity, implying a loss of about 230,000ha of irrigated land, leading to only 410,000ha irrigated. Small scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew et al., 2010).

Besides poor performance of irrigation projects, to compare relative performance and performance assessment is not common in the majority of the constructed schemes in Ethiopia. However to achieve sustainable production from irrigated agriculture it is obvious that the utilization of the important resources in irrigated agriculture, water and land, must be improved. The question- how is irrigated agriculture performing with limited water and land resources has not been satisfactorily answered. This is because we are not able to compare irrigated land and water use to learn how irrigation systems are performing and what the appropriate targets achievement are (Molden et al., 1998).

The same is true for Mojo Asha and Adano small scale irrigation schemes. These schemes were designed and constructed in 1998 and 2000 E.C to develop 75 and 120 ha of the land respectively. The schemes were serving to 300 houses hold in Mojo Asha and 450 house hold in Adano during the first few years after commissioning. However, with an increase in irrigated areas and users, irrigation water management and water allocation are becoming more complex and problematic. Disputes are already common, especially between upstream and downstream users. In addition there are large discrepancies between management targets and actually implemented like water supply versus demand are the main problems in these schemes.

Therefore, performance assessment is used to identify the present status of the scheme with respect to the selected indicators and will help to identify 'why the scheme is performing so' which in turn imply means of improvement (Ayana and Awulachew, 2005). Having this concept the main aims of this study was to evaluate and compare the performance of selected irrigation schemes based on management, production and physical performance indicators to know performance of schemes for more production of land and water.

## 1.3 Objectives

### General Objective

The main objective of this study is to assess performance of Mojo Asha and Adano small scale irrigation schemes using comparative indicators.

### Specific Objectives

The specific objectives of this study are:

- To determine the internal service delivery level of performance within each scheme;
- To compare the performance of selected small scale irrigation schemes using comparative indicators and;
- To identify performance gaps and propose improvement measures.

## 1.4 Research questions

The study will answer the following questions:

- What is the level at which the irrigation practices are being performed?
- Which scheme is performing relatively better?
- What are the factors for performance gaps?

## 1.5 Significance of the study

This study tries to assess and cross compare performance of selected small-scale irrigation schemes. One particularly pressing resource management challenge to our country is to improve the performance of small-scale irrigation systems. These systems will play an important role in providing food for the country's growing population. At the same time, they have potential to waste, even degrade and water resources. In recognition of both the promise and hazards associated with irrigation, assessing and comparing irrigation performance has now become paramount importance.

This study will provide information for the performance or productivity of the current irrigation schemes and information for further improvement and investment approaches for implementing agents (GOs, NGOs, research centers, contractors, etc). It will give insights the impacts of intervention and directions for policy makers. It will also uses as a benchmark and entry point for development works and future studies.

### 1.6 Scope of the Study

The study focuses on undertaking comparative performance assessment of two communities based small scale irrigation; namely Mojo Asha and Adano schemes. Selected relevant comparative performance indicators were applied for comparison in terms of various criteria such as water productivity, land productivity and physical sustainability. In addition, for each scheme the internal irrigation service delivery (conveyance) and on-farm irrigation water management practices was assessed. The expected out puts of this study were:

- The level of the performances of the schemes will be identified and evaluated,
- Current performance status of the schemes will be identified and compared,
- Performance gaps will be identified and improvement measures will be proposed.

### 1.7 Organization of the Thesis

The organization of the thesis totally contains five chapters. Chapter one includes background, statement of problems, objectives, research questions, significance and scope of the study. Chapter two contains the detailed literature review part. While chapter three focused on material and methods followed; which includes description of the study areas, data collection methods and data analysis techniques). Chapter four contains the result and discussion of the research findings while chapter five includes conclusion and recommendation of the final findings of this thesis work.

# 2 LITERATURE REVIEW

## 2.1 Irrigation Water Management

### 2.1.1 Overview of Irrigation water management

Irrigation water management is the process of determining and controlling the volume, frequency, and application rate of irrigation water in planned and efficient manner. According to Salman et al. (1999), "Water management" is defined as the planned development, distribution, and use of irrigation water in accordance with predetermined objectives and with respect to both quantity and quality of the water resources. It is the specific control of all human intervention on surface and subsurface water. Every planning activity that has something to do with water can be looked upon as water management in the broadest sense of the term.

Irrigation water management has become a central issue in many countries, in particular after recent studies, which revealed the disappointing performance of many irrigation schemes. Inefficient water use and inadequate water management, both at farm and scheme level, mean much less area can be irrigated than planned, and agricultural production falls well below target (Mehta, 1994).This implies many irrigation schemes a large discrepancy exists between design assumption and operational reality. This complex interrelation between the design assumptions, water delivery ratio and operational realities are useful to discern the major parts involved for the performances of the schemes.

Simply well planned and well constructed irrigation schemes cannot maximize the benefits unless the systems are well managed and organized**.** Even the crop is sown and produced under absolutely identical conditions using different amount water depth, the yield found to vary (Garg, 1989). Renault (1999) stated that effective irrigation management requires reliable performance assessment. Good farm irrigation management assures correct frequency of irrigations, correct application depth, uniform irrigation, minimum runoff, and minimum deep percolation except for that required for salt management, minimum erosion, and optimal return on irrigation investment. According to Vidhya et al. (2002) good management, proper and timely application of water may result in better yield and reduction in drainage problems.

Irrigation water management within irrigation schemes involves three phases: planning, operation and evaluation (Molden and Gates, 1990; Gorantiwar, 1995). The success of irrigation water management in the irrigation scheme depends on appropriateness of all these processes. And also Water management includes the design of a water delivery system, and social organization of water management, e.g., through Water User Associations. In addition the responsibility for the management of the on-farm water distribution and the water application belongs to an individual farmer. The management is responsible for the operation and maintenance of the irrigation and drainage system. Generally, three management levels can be distinguished these are; conveyance or main level by the government or an irrigation authority, off-farm distribution or tertiary level by a group of formally or informally organized farmers or water users, e.g., in a water users' organization and field level or on-farm distribution and application system managed by the farmer (Depeweg, 1999).

According to James (1988), the performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed, and applied, and by the adequacy and uniformity of application in each field on the farm. Mishra and Ahmed (1990) also said that irrigation efficiency indicates how efficiently the available water supply is being used, based on different methods of evaluation. The objective of these efficiency concepts is to show where improvements can be made, which will result in more efficient irrigation. Generally management of the application of water to land or irrigation water management is important within each irrigation scheme for achieving the benefits of the earlier activities and investment in creating the irrigation potential.

2.1.2 Water delivery system

The conveyance and distribution of water from the main intake to the different farmers fields is refer to as the farm irrigation system. Much of the losses and inadequacies of irrigation systems occur at this level. Watercourses are used to convey water from canals to farmer's field. A large amount of water is lost in these watercourses because of high conveyance losses during its way to the farms level. Seepage, percolation, cracking and damaging of the earthen watercourses are the main causes of poor conveyance efficiency (Ali, 2011). According to Arshad et al. (2009) Water losses in the improved or lined and un-improved or unlined watercourses ranged from 35-52 % and 64-68 % respectively. Sarwart et al. (2001) reported that farmer got more discharge at the inlet of their fields when conveyance losses reduced which had a significant effect on water distribution.

It should be kept in mind that irrigation schedules must be simple, in particular in irrigation schemes where many farmers are involved. It will often be necessary to discuss with the farmers the various alternatives and come to an agreement which best satisfies all parties involved (FAO, 1989).

### 2.1.3 Irrigation Water Control

It is insufficient to simply look at the inputs and outputs of an irrigation project. It is absolutely necessary to understand the internal mechanisms of irrigation projects, and to provide selective enhancement of those internal mechanisms, if irrigation project performance is to be improved (Burt and Styles, 1999). Gradually growing competence over scarce water resource is increasing year by year which especially under such conditions the tail-end farmers are the most vulnerable users, e.g. from mismanagement of water at upper reaches the tail-end farmers may suffer from unavailability of the resource when it is their turn.

Operating an irrigation scheme without hydraulic structures is like trying to drive a car downhill without a break or steering wheel plus you cannot control your speed and you cannot control where you are going. With the help of hydraulic structures, water reaches the fields at the proper time and in the quantities needed (Van den Bosch et al., 1993). Keeping water control structures in operating conditions and managing this scarce resource should be the priority in irrigation scheme operation to attain its objectives.

### 2.1.4 On-farm irrigation water management

Traditional irrigation practices, low crop production due to low water and land productivity, un even distribution of water in the field due to un leveled fields, low irrigation efficiencies due to water losses taking place during conveyance and application phases are the main problems of the common farmers in Ethiopia. According to Gupta et al. (2003), water productivity at field level can be improved by resource conservation technique i.e. laser land leveling. Review of existing literature on land leveling showed that encouraging influence on water saving and crop productivity (Jonish, 1991; Ren et al., 2003; Mallappa and Radder, 1993). Water distribution, germination and yield of crop can be improved by effective application of precision land levelling (Rickman, 2002). Fahong et al. (2003) reported that furrow irrigation under raised bed technology saved more than 30% of irrigation water against traditional flood irrigation.

## 2.2 Performance evaluation of irrigation schemes

The performance of irrigation system is the degree to which it achieves desired objectives. As many Community based irrigation Systems do not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identify specific areas in need of improvement (Abernethy, 1986; Bos, 1997). Because irrigation performance is the result of different activities such as planning, design, operation of facilities, maintenance and application of water to the land or water management (Small & Svendsen, 1992). Other author argued that irrigation performance is the result of agricultural production, land settlement, maintenance, construction, water users' organization, etc. (Nijman, 1992).

Public agencies in many developing countries want to assist farmer-managed irrigation systems improve their performance through better management. This means dependent upon appropriate methods and measures by which system performance can be evaluated relative to the management objectives (Oad and Sampath, 1995). Hence, reliable measures of system performance are extremely important for improving irrigation policy making and management decisions.

Performance evaluation should identify at least problems such as applying irrigation water too little or beyond to the crops. Over supply of irrigation water has contributed to the rise of ground water table to the effective plant root zone. For example on some farms of the middle awash, about 30% of the area has gone out of production due to accumulation of excess salts on the surface caused by the rise of ground water table and the poor distribution of water over the field (FAO, 1995). This indicates that lack of follow up performance assessment from time to time. The main objective of Performance evaluation of irrigation schemes is to determine the efficiency of the system as it is being used and to identify management practices (Merriam et al., 1983; Walker, 1989).

### 2.3 Performance gaps existing in irrigation schemes

There are different Performance gaps existing in irrigation schemes such as deficiencies in water course system, insufficient or no land development, insufficient provision for drainage and absence of controlling devices. Defects in design and construction of the system are a technological performance gap (Douglas and Juan, 1999). According to McIndoe et al. (2005) there are gaps in our knowledge of well performance and well efficiency and lack of knowledge of irrigated agriculture on the part of farmers due to lack of training programs and untrained staff.

The damage to the physical structure and lack of environmental conservation that cause siltation, absence of equity between social in water distribution, lack of irrigation scheduling according to design document, lack of proper operation and maintenances are some examples of low performance of the systems and cause food insecurity in the country (e.g Ayana and Awulachew, 2005; Hundie, 2006).

Improving performance can be achieved, if schemes are designed properly, constructed properly and well managed. According to Elias (2011), even if some technical changes are effective at the end of the construction, still there are gaps between intended and actual result of the project. Therefore, improvement of efficiency can improved equity in water distribution and can minimize the gap between potential crop water requirements and actual water use. In consequence, it will lead to the determination of the effectiveness of water use and lead to the improvement the livelihood of people.

Performance gaps existing in irrigation schemes also improved in different way such as procedural reforms, technical and management training to farmers, formation of water user's organizations, and changes in practices governing staff incentives, major changes in organizational structures and recovering of water charges. According to Molden et al. (1998) performance is assessed for a variety of reasons: to improve system operations; to assess progress against strategic goals; as an integral part of performance-oriented management; to assess the general health of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance; and to compare the performance of a system with others or with the same system over time. The type of performance measures chosen depends on the purpose of the performance assessment activity. Generally performance assessment is hasn't option solution for performance gaps.

## 2.4 System performance indicators

The performance indicator of an irrigation scheme is represented by its measured levels of achievement in terms of one, or several, parameters which are chosen as indicators of the system's goals (Abernethy, 1986). This implies performance indicators are measurable variables which describe the condition of the system. According to Yashima (1997) performance indicator is ratio of actual performance to target performance.

Many internal indicators relate performance to management targets such as timing, duration, and flow rate of water, area irrigated and cropping patterns. A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of system management and performance measures tell how well the system is performing relative to these targets (Molden et al., 1998). These "internal" indicators aid irrigation system managers to answer the question "Am I doing things right?" (Murray-Rust and Snellen et al.,1993).

A true performance indicator includes both an actual value and an intended value that enables the assessment of the amount of deviation. It further should contain information that allows the manager to determine if the deviation is acceptable. Some of the desirable attributes of performance indicators suggested by (Bos, 1997) are: Scientific basis, the indicators must be quantifiable, reference to a target value, Provide information without bias, ease of use and cost effectiveness, Particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment and commitment of human resources, should be well within the agency's resources.

An irrigation system, consisting of a water delivery and water use subsystems, can be conceptualized to have two sets of objectives. One set relates to the outputs from its irrigated area, and the second set relates to the performance characteristics of its water delivery system (Oad and Sampath, 1995). The performance indicators summarized by (Bos, 1997) currently used in the Research Program on Irrigation Performance (RPIP). Within this program field data are measured and collected to quantify and test about 40 multidisciplinary performance indicators. These indicators cover water delivery, water use efficiency, maintenance and environmental aspects, socio-economic and management.

## 2.5 Comparative performance indicators

Many authors and researcher have proposed indicators to measure irrigation system performance. But, there are very few examples of cross-system comparisons. Recent studies have attempted to standardize these indicators to allow for better comparison across systems (Bos, 1994). An approach to cross-system comparison is to compare outputs and impacts of irrigated agriculture. According to Molden et al. (1998) external indicators are used to relate outputs from a system derived from the inputs into that system.

Generally, The objective of using comparative indicators is to evaluate outputs and impacts of intervention in individual systems, compare performance of a system over time, and also to allow comparison of systems in different areas and at different system levels (Molden et al., 1998). The International Water Management Institute (2007) suggests that using a minimum set of comparative indicators (e.g relative water supply, relative irrigation supply and Water delivery capacity) to assess hydrological, agronomic, economic, financial, and environmental performances of irrigation systems. Other author says that comparison aims to improve the performance of the schemes by identifying shortcomings and benchmarking best practices (Malano et al., 2004).

Molden et al. (1998) have summarized three groups of comparative performance indicators: agricultural output, water supply and financial indicators. The application of these indicators was described at 18 schemes located in 11 different countries based on data collected by the International Water Management Institute (IWMI) and collaborators (Molden et al., 1998). Similarly, Kloezen and Garcés-Restrepo (1998) applied these indicators to assess the Alto Rio Lerma Irrigation District in Mexico. However, Dejen et al. (2012) applied agricultural output, water supply and physical indicators to evaluate and compare the performance of two community-managed irrigation schemes; namely, Golgota and Wedecha with two sub-systems Godino and Gohaworki located in Central Ethiopia. Similarly, in this study financial indicators were not included as they are irrelevant to the systems under consideration (irrigation water fee is completely absent in both schemes). Instead, physical indicators were used.

## 2.6 Irrigation schemes performance studies in Ethiopia

Yusuf (2003) has assessed Batu Degaga and Doni small scale irrigation using comparative performance indicators. He investigated that application efficiencies of the farmer's field from the two irrigation projects varied from 31.46% to 64.29%. The soils of study area are mostly medium textured which ranges from silty loam to sandy loam and crop type such as maize, tomato, beans and mango. From analysis outputs per cropped area of the two projects were more or less equal (5,027.25 birr/ha for Batu Degaga and 5,018.90 birr / ha for Doni) but the value of the output per command area of Doni (7,590.00 birr per ha) was greater than the value of Batu Degaga (6,625.83 birr/ha). The output per unit irrigation supply for Batu Degaga was 1.14 birr/$m^3$ while Doni was 0.67 birr/$m^3$. Output per water consumed varied from 2.45 to 1.14 birr/$m^3$ for Batu Degaga and Doni respectively. He concluded that regarding the output per area, Doni was better than Batu Degaga, but for the output per water supply the inverse was true that is Batu Degaga was better than Doni. Since the intention of the analysis was to investigate how the performances of the irrigation projects were consistent, Doni irrigation has been performing better than Batu Degaga.

Other researcher also studies Batu Degaga and Doni irrigation schemes which were evaluated performance and environmental impact assessment of community based irrigation in the Awash basin. In order to evaluate the irrigation water use efficiency of farmers at field level, he was selected three farmers from each irrigation schemes from the head, middle and tail end water users. The soils of study area are mostly medium textured which ranges from silty loam to loam and crop type such as mango, orange, sugarcane, tomato and maize. In your study showed that the application efficiencies of upstream, middle and downstream fields were 53.75%, 53.87% and 31.46%, at Batu Degaga while 59.00%, 50.6% and 64.29% at Doni respectively. He also analyses the comparative performance indicators using relative water supply and irrigation water supply. In your result the ratios of RWS and RIS were 2.34 and 2.73 for Batu Degaga while 1.67 and 2.4 for Doni Kombi irrigation schemes, respectively. He concluded that in terms of water, irrigation water was not a constraint and higher amount of water was diverted (over supply of water) at Doni than Batu. even though water was not a free resource, farmers were applying excess amount of water to their fields without considering the crop water requirements of the crop. The distance of the field from the water source did not limit the farmers from applying excess water (Getahun, 2008).

Leliso (2008) has evaluated technical performance of woter small-scale surface irrigation system. The evaluation was made using selected performance indicators such as conveyance, application, and water productivity in terms of water use efficiency. In this study the main canals conveyance efficiencies for 300 m canal reaches at various locations were 85.1% and 88.5% for left and right command area, respectively. He also examined three selected farmer's fields which is head, middle and tail-ends. This study showed that the average application efficiencies of upstream, middle and downstream fields were 45.8%, 62.0 % and 69.2%, respectively. Water productivities (in terms of water applied) has an increasing trend from upstream to downstream fields and the values were of 13 Birr/$m^3$, 20.5 Birr/$m^3$ and 21 Birr/$m^3$ respectively. Whereas, the productivity (in terms of water consumed) has values of 22.9 Birr/$m^3$, 31.2 Birr/$m^3$ and 25.1 Birr/$m^3$. He concluded that the application efficiency is mainly related to the management of water at field level, and the finding indicates that the downstream irrigators were the most efficient in applying water to their fields as compared to the middle and downstream irrigators.

Dejen et al. (2012) has conducted the performance of two community-managed irrigation schemes in Ethiopia with comparative (external) indicators. Three groups of comparative performance indicators, that is, water supply, agricultural output and physical indicators were used to assess Golgota and Wedecha Scheme with two sub-systems Godino and Gohaworki. The results showed that while annual irrigation supply at Godino sub-system matched well to demand, at Golgota Scheme and Gohaworki Sub-system, excessive irrigation water was supplied with annual relative irrigation supply (ARIS) values of 3.17 and 1.90, respectively. Excess irrigation supply to Golgota Scheme is due to two important factors. First, it is the fact that farmers themselves are responsible for the volume of water diverted from the river; unlike Wedecha Scheme. So, water is diverted without due consideration of demand and monthly variations of relative irrigation supply (RIS) are high. Secondly, an important factor for excess irrigation supply is the fact that there is no irrigation water fee at Golgota Scheme. However Golgota Scheme had better land productivity in the region due to more intensive irrigation and better investment, it had poor water productivity due to uncontrolled water diversion and absence of irrigation water fee. Godino sub-system could be benchmarked in the region for water productivity; while land productivity at Golgota could be taken as a promising indicator. Irrigated areas at Wedecha (both sub-systems) were found to be contracting while it was expanding at Golgota due to more generous irrigation water supply for free.

A similar research in Ethiopia has evaluated the performance of three small-scale irrigation schemes namely, Arara, Woter-02 and Hajifaja schemes using selected performance indices like water supply and agricultural output. The soils of study area are mostly clay and crop type such as maize, tomato, potato and pepper. From analysis of water the Relative Water supply were 1.1, 1.4 and 1.8 at Hajifaja, Arara and Woter-02 schemes respectively, and Relative Irrigation Supply is 1.1, 1.6 and 2.1 at Hajifaja, Arara and Woter-02 schemes respectively. The results indicate that released water from diversion is more than the requirement; it can develop extra command if managed properly. The production output results include agricultural inputs. Output per unit irrigated command area in Birr/ha was 190,386, 210,701 and 213,622 at Arara, Hajifaja and Woter-02 scheme respectively. Outputs per unit irrigation water supply were 12, 15 and 25 Birr/$m^3$ at Woter-02, Arara and Hajifaja scheme respectively. Output per unit irrigated water delivered is 16, 17, and 30 Birr/$m^3$ for Woter-02, Arara and Hajifaja scheme respectively. Whereas outputs per unit water supply were 10, 11 and 17 Birr/$m^3$ at Woter-02, Arara and Hajifaja scheme respectively. Depending on result it concluded that hajifaja scheme was performing better than Arara and Woter-02 schemes (Abdi, 2015).

Generally, with regard to this, the problems within irrigation schemes did not generally related to the basic engineering or hydraulics of irrigation. Factors that affect the productivity of schemes are poor water management, farm structures' deterioration and improper irrigation schedule. Furthermore, it had obvious that, little attention was paid to O & M of irrigation systems.

# 3 MATERIALS AND METHODS

## 3.1 Description of the study area.

### 3.1.1 Location of study area

The study area is found in Oromiya region East Hararghe zone, in Girawa Woreda. The Woreda is bordered by Haramaya and Fadis woreda in east, Bedano woreda in the west; Meyu woreda in south and Kurfa calle in north (Figure 3.1). The capital Town of the woreda is Girawa Town located to the west of Harar and at a distance of 75 km from Harar Town.

Mojo Asha small-scale irrigation scheme is located in Girawa woreda, East Hararghe Zone at the Asha Peasant Association. The scheme head work is geographically located at 41°39'16" E longitude and 09°06'07" N latitude, and an altitude of 1600 m a.s.l.

Adanoa small-scale irrigation scheme is also located in Girawa Woreda, East Hararghe zone at the Tarre Peasant Association. The scheme head work is geographically located at 41°44'13" E longitude and 09°08'20" N latitude, and an altitude of 1550 m a.s.l. (Figure 3.1).

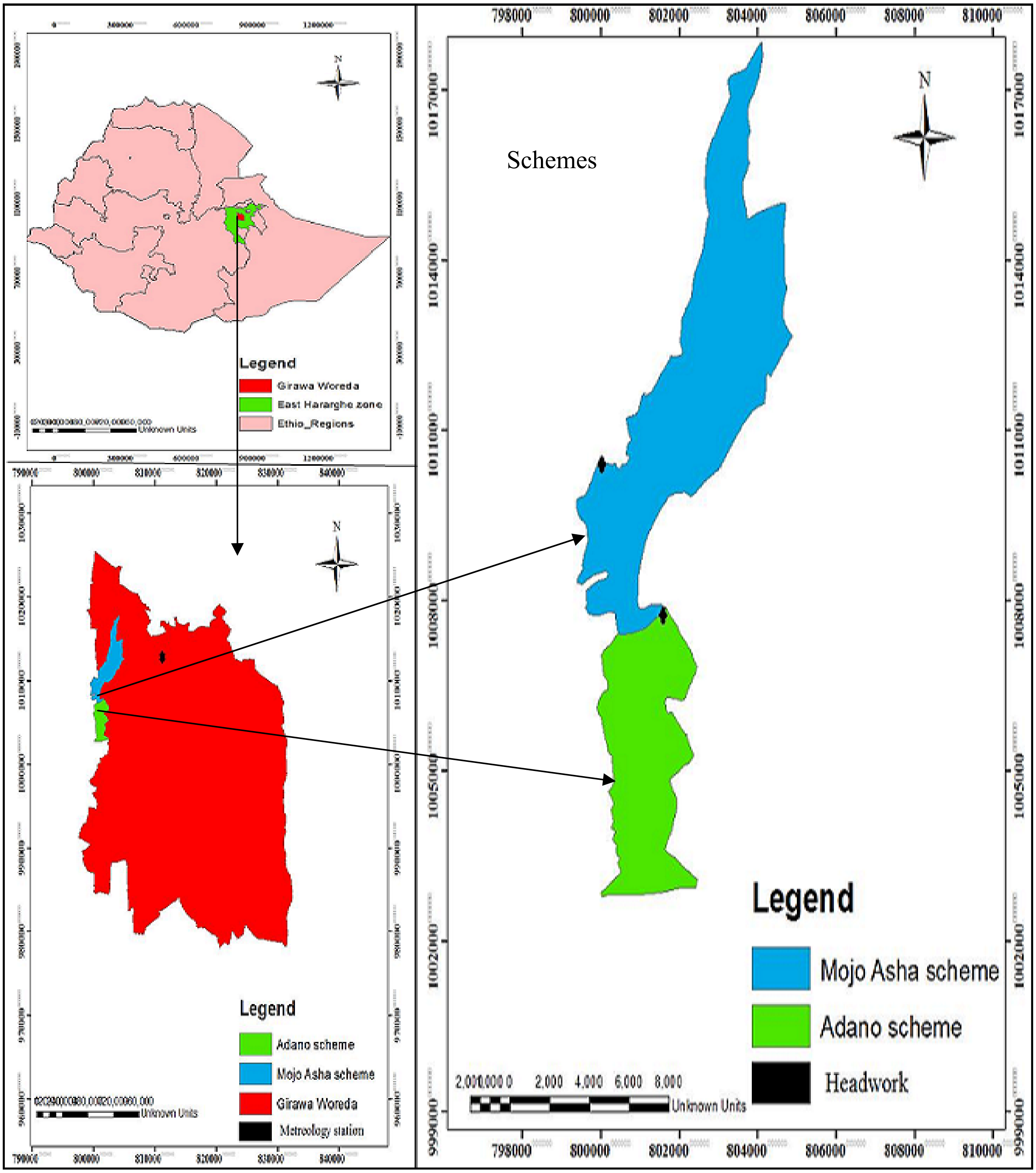


Figure 3.1: Location Map of the Study Area.

### 3.1.2 Topography and climate condition

Large area of the Woreda is characterized by undulated and rugged landscape. Agro-climatically, the district encompasses highland 71%, midland 20% and lowland 9% with altitude ranging from 1250 to 2600 meters above sea level at Baladi and Garamulata Mountain respectively (Woreda Agricultural office, 2016). According to same source woreda was categorized under Moist Weyna Dega agro climatic zone. The climatic data of the study area were collected from the Girawa meteorological station which is 3.7 and 5 km far from Mojo Asha and Adano small scale irrigation schemes respectively. The annual rainfall of twenty three years meteorological data of Girawa station (1993-2016) showed that the average monthly rainfall is 76.7 mm from the total average annual rainfall about 80% is received from April to September. The Woreda gets biannual rainfall the 'Belg' (short season, from the end of March to the middle of May) and 'Meher' (long season, from July to the end of September).

Temperature data from Girawa station of twenty three years (1993-2016) showed that January month account for the minimum average temperature of 10.2$^{o}$C. But the maximum average temperature is 23.01$^{o}$C on the month of March. The mean average annual temperature is 16.63$^{o}$C.

Relative humidity data from Girawa station of five years indicate that, the highest maximum average relative humidity is 75.8% on the month of August and the lowest minimum average relative humidity is 55.4% on the month of December. The mean average annual Relative humidity is 65%.

According to five-year data, the maximum wind speed is 9.88 km/hrs in the month of July, and the minimum wind speed is 4.10 km/hrs in the month of October. The mean average annual wind speed is 6.85 km/hrs.

### 3.1.3 Demography and population

The majorities of the population of the Woreda live in the rural area of the district and depend on crop production and livestock rearing to support their livelihood. From total population of the Woreda lives in rural area male is 126,172 and female is 124,162 this indicates a total population of the rural area is currently 250334. From the total population of the about 90% live in rural area while the remaining lives in urban areas (Woreda Agricultural office, 2016).

### 3.1.4 Land use Pattern

According to Woreda Agricultural office (2016), land use pattern of the district large area is covered by agricultural land about 70% and followed by Rugged and mountain land (Table 3.1)

Table 3.1: Land use pattern of Woreda

| S, No | Type of land use | Area in Ha | Percentage |
|---|---|---|---|
| 1 | Agricultural land | 50101.1 | 70 |
| 2 | Forest Land | 1789.325 | 2.5 |
| 3 | Bush and Shrubs | 3671.695 | 5.13 |
| 4 | Residence and others | 6706.39 | 9.37 |
| 5 | Rugged and mountains | 7873.03 | 11 |
| 6 | Grazing Land | 1431.46 | 2 |
| | Total Land | 71573 | 100 |

Source: Woreda Agricultural office, 2016

## 3.2 Description of Irrigation under Study

### 3.2.1 Mojo Asha Irrigation Scheme

*A) Source of water*

The source of water for this scheme is Hamid River which comes from under the foot of Garamuleta Mountain. It is found in the Wabi Shebele River Basin. According to information obtained from local elders indicate that before the project was established in 2006 farmers were irrigating about 28 ha of land using temporary diversion structures to produce grains and other crops. These temporary structures were laid at some angle to the river flow directions and supply canals are extended to the field where irrigation was taking place. The construction of the temporary diversion structures is carried out during the dry season when water volume reaches minimum (base flow). Such construction truly requires the use of much labor and locally available material. After long period of temporary diversion structures they got the chance of modern diversion head work in 2006. The International Fund for Agricultural Development (IFAD) was covered the project cost.

According to design document (2006), the total discharge was 80 l/sec and it was irrigated 75 ha of the land. The 9.5 ha of the land is located at the right bank for 39 beneficiaries and 65.5ha of the land is located at left bank of the scheme for 262 beneficiaries. There are different PA benefits from Mojo Asha irrigation scheme. From the right bank at the head user only Barre village are uses. From the left bank at the head Asha and Abdulla villages are users, at middle Kabira and Dire villages are users and at the tail Hiyo village is benefit from this scheme.

*B) Soil and topography of the scheme*

The soil was formed colluvial and alluvial deposits transported from the surrounding hill sides through runoff action and seasonal inundation of the river during summer. The parent material is limestone, which is the same as that of catchments area. According to design document (2006) and Woreda Agricultural office (2016) the soil distribution of the study area is 10% sandy loam, 25% silt loam, 35% clay loam and 30% loam. Mojo Asha irrigation schemes was bounded with chain of mountains at the right and left side of the scheme. The slope of study area varies from (1-8%) and undulating topography (3-8%) effective soil depth.

3.2.2 Adano Irrigation Scheme

*A) Source of water*

The source of water for this scheme is known as Aminura spring. It is found 3km in the river bank of downstream of Mojo Asha irrigation scheme. It is also found in the Wabi Shebele River Basin. According to information obtained from local elders indicate that before modernization the local farmers have been diverting water using local material like wood, stone and soil during the irrigation time. The farmers of this area have deep awareness and experience of diverting the river traditionally. The construction of traditional irrigation scheme is carried out during the dry season when water volume reaches minimum. The scheme was upgraded to modern diversion head work in 2008. The International Fund for Agricultural development (IFAD) was also covered the project cost.

According to design document (2008) the total discharge was 110 l/sec and it was irrigated 120 ha of the land. From this scheme 450 households are beneficiaries. It has only one canal known as Masno Tarree (Tarree canal). According to interview farmers during study indicate that there are different PA benefits from this scheme. These are at the head users Tarre and Qalata village, at middle user’s liya and soma part of Adano gult village and also at tail users Adano gulti village is benefit from this scheme.

*B) Soil and topography of the scheme*

The Adano irrigation schemes was also bounded with chain of mountains at the right and left side of the schemes. The soil was formed colluvial and alluvial deposits transported from the surrounding hill sides through runoff action and seasonal inundation of the river during summer. The parent material is limestone, which is the same as that of catchments area. According to design document (2008) and Woreda Agricultural office (2016) the dominant soil type found in watershed area is clay and clay loam, which cover the high land and subtropical (humid) part of catchments. Soils of low land of watershed are sandy loam, clay loam and clay, which are more fit and suitable for crop production. The landforms in and around the study area is gentle slope about 1-5% and 6-10% approximately of sleepy slope. Vegetation cover of catchments, especially the high land and subtropical humid part of the watershed is very high. Most of these parts of catchments are natural forest.

3.2.3 Irrigation practice in the schemes

The irrigation water management practices in the schemes are like elsewhere in Girawa woreda. It is handled by the beneficiaries themselves through the appointment of a person locally name "Melaka" who is responsible for the proper distribution of the water for each user. Through by laws (unwritten agreement) it is reported by farmers that the P.A administration is actively involving in decision making on issues which are beyond the control of the beneficiary farmers.

According to their bylaws, the beneficiaries have agreed on various issues like individual rights and also responsibilities, penalty measures up on members who fail to follow their communal agreement and also irrigation water usage mechanisms. Hence, every user or beneficiary household has the right to use the irrigation water as per the sequence of requests made to the melaka and his permission. If someone tries to use water without permission and also fail to participate during communal work without tangible reasons they are supposed as punishment and they will punish according to their bylaw. The money obtained through such measures will be utilized for buying chat and preparing "Hoja" a local hot drink at the time of campaign or maintenance work. However, if the person admits his wrong doings and ask for excuse, the community may deduct or cancel the punishment.

The distribution can be allocated day and night rotation or for specific period (days interval). As far as the schedule of irrigation water allocation for the farmers, they have the right to apply the water as much as wants. That means there is no any restriction how much water the farmer can divert for his field regardless of the size of his farm, especially for head end users.

### 3.2.4 Crops grown in the schemes

Most of the farmers grow crops three times in a year. The first one is from September to December when the tomato, onion and pepper are the major crop grown and covers 80.8% of the cultivated land. The remaining estimated coverage is 13.7% by maize and 5.5% of other vegetables like potato and cabbage. The second is from January to April when maize cover 45 % the land and 55% are covered by pepper, onion, potato and cabbage in Mojo Asha irrigation scheme (Table 3.2). The third season is from May to August when cereals crops like sorghum, Barley and others are grown as rain-fed.

In Adano irrigation scheme the maize, potato and tomato are the major crops grown and covers 74.2% of the cultivated land. The remaining estimated coverage is 20% by pepper and onion and 5.4% of other vegetables like cabbage. The second season maize crop cover 50 % the land and 50% are covered by pepper, onion, potato and cabbage (Table 3.3). The third season was the same as Mojo Asha scheme the cereals like sorghum, Barley and others are grown as rain-fed crops.

In irrigation schemes there is no any rule or restriction on the farmers what type of crop to produce. The types of crops to be grown are selected based on the market condition, the resistance of the crop for disease and water availability. The farmers sell their produce by themselves based on the market price. Their production is accessible to market e.g., tomato, potato, onion and peppers are export to Harar, Dire Dawa, Somalia and Djibouti.

Table 3.2: Crops growth and their intensity in Mojo Asha scheme

| Mojo Asha Scheme | | | | | |
|---|---|---|---|---|---|
| S. No | Crop Type | $1^{srt}$ season | | $2^{nd}$ season | |
| | | Area (ha) | Crop Area (%) | Area (ha) | Crop Area (%) |
| 1 | Tomato | 28.5 | 43.5 | 5 | 9.8 |
| 2 | Pepper | 13 | 19.8 | 10 | 19.6 |
| 3 | Onion | 11.5 | 17.6 | 9 | 17.6 |
| 4 | Potato | 2.5 | 3.8 | 2 | 3.9 |
| 5 | Maize | 9 | 13.7 | 23 | 45.1 |
| 6 | Cabbage | 1 | 1.5 | 2 | 3.9 |
| | Total | 65.5 | 100.0 | 51 | 100.0 |

Source: Woreda Agricultural office, 2016

Table 3.3: Crops growth and their intensity in Adano scheme

| Adano Scheme | | | | | |
|---|---|---|---|---|---|
| S. No | Crop Type | $1^{srt}$ season | | $2^{nd}$ season | |
| | | Area (ha) | Crop Area (%) | Area (ha) | Crop Area (%) |
| 1 | Tomato | 18.5 | 14.2 | 10 | 9.1 |
| 2 | pepper | 13.5 | 10.4 | 12 | 10.9 |
| 3 | Onion | 13 | 10.0 | 13 | 11.8 |
| 4 | Potato | 40 | 30.8 | 17 | 15.5 |
| 5 | Maize | 38 | 29.2 | 55 | 50.0 |
| 6 | Cabbage | 7 | 5.4 | 3 | 2.7 |
| | Total | 130 | 100.0 | 110 | 100.0 |

Source: Woreda Agricultural office, 2016

From (Table 3.2 and 3.3) tomato, potato, onion, and pepper are the main vegetable crop grown in the study area during the first growing season while maize was the main crop grown in the study area during the second growing season. According to information obtained from farmers during second growing season there were different diseases which affect crop production. These diseases are simply affect crops like tomato and onion. In order to reduce this problem the farmers select maize rather than other crops during second growing season.

**3.3 Source of data**

The data collection had been carried out in collaboration with DAs in the kebele, the Woreda Agricultural Office expert, and farmers were consulted about the general condition of irrigation scheme. From October 2016 to November 2016 a comprehensive field survey was made to each scheme by walking through the different components of the schemes.

- To determine data collection procedures;
- To understand how data will be collected with minimum cost;
- To understand the water conveyance and distribution systems and quickly evaluate their conditions;
- To understand the existing irrigation scheduling and operation of flow control structures;
- To assess on-farm and off-farm irrigation water management practices. Moreover, the field survey enables measurement and facilitate data collection method and also provides lots of information in a relatively short period of time.

3.3.1 Primary data

Actual field investigation and measurements or survey works including simple observations of scheme at the sites was required to collect the necessary data to know the present condition of the scheme. Primary data collection activities were included three components:

- Frequent field observations of practices related to water management by farmers,
- Field measurements related to canal water flows of farm fields and soil moisture contents,
- To establish the production data and cost of production using a questionnaire survey.

### 3.3.2 Secondary data

Secondary sources were collected from Woreda Agricultural Offices, Zonal and Irrigation Offices at Regional levels. These data included total command area, irrigable area, irrigated area, crop types, and cropping pattern and design documents. The climatic data of irrigation projects were collected from the nearby Girawa meteorological station. The reliability and consistency of these data were checked through survey and observations of different irrigation system.

## 3.4 Methodology

### 3.4.1 Overview of method

For discharge measurement, the main canal was divided into three reach i.e., upstream, middle and downstream reach which is represents high, medium, and low, water accessible areas respectively. Average landholdings of farmers at head, middle and tail reaches of each scheme were determined. A number of farmers have been selected from each reach to provide information on farming and land hold. Ten randomly selected farmers were interviewed from each reach that is 30 for each scheme and total 90 farmers interviewed. From three reach or locations three farms were also selected to estimate the application efficiency of the schemes as shown in (figure 3.2 and 3.3). The criteria for selection of farms field have been their similarity with water management practices and willingness of the farmers to collaborate. The schematic layouts of both schemes are illustrated in (figure 3.2 and 3.3) and briefly explained in the next section.

Irrigable land could either be fully or partly utilized for cropping throughout the year depending on various factors. Irrigable land is the size of land which could be irrigated with the designed irrigation infrastructure. In this study, it was determined by surveying the areas with the global positioning system (GPS). The irrigated cropped area is the sum of the areas under irrigated crops during all cropping seasons in a year and depends on irrigation intensity. It was determined using a questionnaire survey (irrigated land holding of sampled farmers and total number of farmers) in combination with secondary data compiled by local agricultural development offices.


Figure 3.2: Schematic layout of selected field and measurement canal in Mojo Asha scheme.


Figure 3.3: Schematic layout of selected field and measurement canal in Adano scheme.

3.4.2 Estimation of canal flow discharge

The measurement of base flow is accomplished by using simple floating method. The discharge was measured in different periods during the low water level in order to get base flow. For first season the discharge was measured from September up to end December 2016 G.C while for second season discharge was measured from January up to end April 2017 G.C using following (equation 3.1).

Measurement of discharge was conducted on the upstream, middle and downstream of the main and secondary canal where the cross-section of the channel is straight, uniform, regular shape and also after the canals was cleaned. The canal length considered at well defined straight channel was fixed at known distance length. Then floating material (piece of dry wood) was putted on the upper end of the canal section and the time it was taken to reach the mark area was registered. The cross-sectional area of the canal was estimated by measuring the average depth and width of the canal section using tape meter. The coefficient factor (0.8) was used to improve the estimate of mean velocity from the surface velocity. The average velocity and the rate of flow or discharge ($m^3$) are calculated by dividing the distance (m) with the time (sec) and by multiplying the cross-sectional area with the average flow velocity, respectively and estimated as follows:

$$Q = A \text{ x } V - - - - - - - - - - - - - - - - - - - - - - - - - 3.1$$

Where Q is rate of flow ($m^3$)

A is cross-sectional area ($m^2$)

V is average flow velocity (m/sec).

3.4.3 Determination of soil moisture content

*A) Soil Moisture Content*

Soil samples were collected to determine moisture content of soil from irrigated fields at depth interval of 30 cm to maximum of 90 cm depth. This depth was considered as effective root zone of the crops at the time of measurement. Depending on soil type the soil samples were taken before and two days after irrigation events. The soil samples were placed in containers of known weight and then weighed. The samples were dried in an oven for 24 hours at temperature of 105°C with the containers cover removed. After drying, the soil and container were again weighed and the weight of water determined as following pre and post readings. The dry weight fraction of each sample was calculated using the equation (FAO, 1989).

$$\theta_w = \frac{M_{(W+s)} - M_S}{M_S} ------------------------3.2$$

Where $\theta_w$ is moisture content by weight basis (%)

$M_{(w+s)}$ is mass of fresh sample before oven dry (g)

$M_s$ is mass of soil after oven dry (g)

Field capacity and Permanent wilting point of the three selected fields from head, middle, and tail were determined in the Haramaya University laboratory using a pressure plate apparatus by applying a suction of 1/3 bar and 15 bar to a saturated soil sample respectively. After it calculated then the moisture content of soil samples were converted to the volumetric water content (θv) by multiplying with bulk density (ρb) as:

$$\theta v = \theta_w \text{ x } \rho_b ------------------------ 3.3$$

Soil moisture content was also expressed in terms of equivalent depth ($\frac{mm}{m}$)

$$\text{Equivalent depth} \left(\frac{mm}{m}\right) = 10 * \theta v \ -------------3.4$$

*B) Bulk density, field capacity and permanent wilting point*

The bulk density was measured using 12 undisturbed soil samples collected per each pit. Samples were collected at 30 cm interval down the pit. Four samples were collected from each interval up to the depth of 90 cm, which were having been assumed to be the root depth for most of the crops growing in the area. The undisturbed samples were weighed and then oven dried at 105°C for 24 hrs. The dried soil samples were having been re-weighed. After determining the core volume by measuring the inner diameter and height, the dry bulk density ($\rho_b$) was computed as the ratio of oven dry weight of sample ($m_s$) to known volume of core sampler($v_t$) (Blake, 1965):

$$\rho_b = \frac{m_s}{v_t} ---------------------------3.5$$

Where $\rho_b$ is dry bulk density ($g/cm^3$)

$m_s$ is oven dry weight of sample (g)

$v_t$ is volume of core sampler ($cm^3$)

*C) Total available water*

Total available water (TAW) is an estimate of the amount of water a crop can use from the soil for the selected fields were computed as:

$$TAW\left(\frac{mm}{m}\right) = (\theta_{FC} - \theta_{PWP}) ---------------- 3.6$$

*D) Moisture storage depth*

The soil moisture storage depth (SMD) which is equal to the actual allowed depletion depth in the selected fields just before at the time of irrigation was computed as (Walker and Skoerboe, 1987):

$$SMD\left(\frac{mm}{m}\right) = (\theta_{FC} - \theta_{BI}) --------------------- 3.7$$

The actual moisture storage or retention (AMS) after irrigation was computed as:

$$AMS\left(\frac{mm}{m}\right) = (\theta_{AI} - \theta_{BI}) -----------------3.8$$

Where $\theta_{AI}$ is moisture content after irrigation (%)

$\theta_{BI}$ is moisture content before irrigation (%)

3.4.4 Determinations of Crop and Irrigation Water Requirements

To estimate the crop water requirements (CWR), irrigation scheduling and irrigation water requirement (IWR) of the irrigated crops at field levels and the irrigation project as a whole the FAO CROPWAT 8.0 was used. The determination of the CWR of the model depends on the determination of the reference evapotranspiration values using the available climatic data (Table 3.3). The determination of IWR was carried out after estimation of effective rainfall by USDA soil conservation service method. The irrigation requirements of each irrigation projects were been calculated with CROPWAT 8.0 using the climatic data, cropping pattern, planting dates, and area of each crop. Therefore the procedure for ETo calculation in the FAO Irrigation and Drainage Paper 56, using the FAO Penman-Monteith equation (Allen et al., 1998) which is given by:

$$\mathrm{ETo} = \frac{0.408\Delta(\mathrm{Rn} - \mathrm{G}) + \gamma \frac{900}{\mathrm{T} + 273} \mathrm{U}_2(\mathrm{e_a} - \mathrm{e_d})}{\Delta + \gamma(1 + 0.34\mathrm{U}_2)} \text{-----------------} 3.9$$

Where, ETo = potential evapotranspiration [mm $d^{-1}$]

$R_n$ = net radiation at crop surface [MJ $m^{-2}$ $d^{-1}$]

G = soil heat flux [MJ $m^{-2}$ $d^{-1}$]

T = average temperature at 2 m height (°C)

U = wind speed measured at 2 m height [m $s^{-1}$]

($e_a - e_s$) = vapour pressure deficit for measurement at 2 m height [k Pa]

Δ = slope of vapour pressure curve [k pa°$C^{-1}$]

γ = psychrometric constant [k pa°$C^{-1}$]

900 = coefficient for the reference crop

0.34 = wind coefficient for the reference crop

The crop water requirement (CWR) and the irrigation water requirement (IWR) were computed for each irrigated crop within two irrigation season (Sept-April). It was necessary to apply the indicators to individual cropping seasons since the climatic conditions for the first and second seasons are very different in terms of irrigation needs. The crop coefficients provided with CROPWAT Computer program were used to calculate the crop water requirements. It was done for each crop, according to the growing season practicing in the study area using CROPWAT 8.0 models considering meteorology data is an input of the model data (Table 3.4).

Table 3.4: Major crop growth in study area used as input data for CROPWAT 8.0

| | | Types of crop growth in study area | | | |
|---|---|---|---|---|---|
| S. No | Type of Crop | Mojo Asha Scheme | | Adano scheme | |
| | | 1[srt] season Area (ha) | 2[nd] season Area (ha) | 1[srt] season Area (ha) | 2[nd] season Area (ha) |
| 1 | Tomato | 28.5 | 5 | 18.5 | 10 |
| 2 | Pepper | 13 | 10 | 13.5 | 12 |
| 3 | Onion | 11.5 | 9 | 13 | 13 |
| 4 | Potato | 2.5 | 2 | 40 | 17 |
| 5 | Maize | 9 | 23 | 38 | 55 |
| 6 | Cabbage | 1 | 2 | 7 | 3 |
| | Total | 65.5 | 51 | 130 | 110 |

Source: Woreda Agricultural office, 2016

### 3.4.5 Determination of Crop Evapotranspiration

Estimation of $ET_c$ is essential for computing the soil water balance and irrigation scheduling. $ET_c$ is governed by weather and crop condition (Smith, 1992). Procedures to estimate $ET_c$ have been well established by FAO Irrigation and Drainage Paper 56, using the FAO Penman-Monteith equation (Allen et al., 1998). Using a series of recommended crop coefficient values ($K_c$) to determine crop evapotranspiration $ET_c$ from reference evapotranspiration ($ET_o$).

The effect of crop characteristics on crop water requirement is given by crop coefficients. Crop coefficient represents the relationship between reference evapotranspiration ($ET_o$) and crop evapotranspiration ($ET_{crop}$). The values of crop coefficient given are varying with the types of crops, its stage of plant growth, growing season and the prevailing weather conditions.

$$ET_C = K_C \text{ x } ET_O -------------------3.10$$

Where $ET_c$ is crop evapotranspiration [mm $d^{-1}$]

$ET_o$ is reference evapotranspiration [mm $d^{-1}$]

$K_c$ is crop coefficient **(-)**

The crop coefficients provided with CROPWAT Computer program were used to calculate the crop water and irrigation requirement at each growth stage. The net crop water requirement (CWR) and the net irrigation Water requirement (IWR) were computed for each schemes for the 2016/17 cropping season was calculated as the follows:

$$NCWR = \frac{\sum_{i=1}^{n} CWR\ crop_i * Cropped\ \ Area_i}{\sum_{i=1}^{n} Cropped\ \ Area_i} \text{--------------} 3.11$$

3.4.6 Irrigation Scheduling

Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper scheduling is essential for the efficient use of water, energy and other production inputs, such as fertilizer. It allows irrigations to be coordinated with other farming activities including cultivation and chemical applications. Among the benefits of proper irrigation scheduling are: improved crop yield and/or quality, water and energy conservation, and lower production costs (James, 1988).

FAO (1989) explained that when surface irrigation methods are used, however, it is not very practical to vary the irrigation depth and frequency too much. In surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all the time. Therefore, it is often sufficient to estimate or roughly calculate the irrigation schedule and to fix the most suitable depth and interval, to keep the irrigation depth and the interval constant over the growing season. To consider the above concepts, the CROPWAT 8.0 computer model was used to perform irrigation scheduling of the schemes.

### 3.5 Data Analysis

After collection of the valuable data from various sources for the respective irrigation projects under investigation, performance analysis were implemented for evaluating their performance using selected performance indicators. In this study there are two types of indicators were determined to evaluate performance of Mojo Asha and Adano irrigation schemes namely: process (internal) and comparative (external) indicators. The aim of applying internal indicators were used to assess actual irrigation performance relative to system specific management goals and operational target while external (comparative) indicators is to evaluate outputs and impacts of interventions across different systems and systems levels (Kloezen et al., 1998). Good performance is not only a matter of high output, but also one of efficient use of available resources e.g water and land (Murray-Rust et al., 1993). Therefore, performance of these schemes were evaluated using internal indicators such as conveyance efficiency, application efficiency, scheme efficiency while comparative (external) indicators, such as water supply and agricultural output set by International Water Management Institute (IWMI) (Molden et al., 1998). These indicators are detailed in the following sub-section.

#### 3.5.1 System Performance Indicators

*A) Conveyance Efficiency ($E_C$)*

An estimate of the amount of water that is lost or mismanaged in the conveyance system is required for effective management decisions and equitable water distribution. Thus it is important to know where the water is going within the conveyance system (Wahaji, 2005). According Bos et al. (2005) stated that the change of the ratio is an indicator for the need of maintenance. Quantifying the outflow over inflow ratio for only one month gives information to the system manager provided that a target value of the ratio is known. A regular repetition of the measurement allows the assessment of the trend of an indicator in time. This assists the manager in identifying trends that may need to be reversed before the remedial measures become too expensive or too complex.

To estimate conveyance of canal, the canal discharge was also determined by floating method conducted on main canal just downstream of the head regulator up to tail end. In order to get Conveyance efficiency (Ec) of canal at different location, canal divided into three locations depending on water accessible that is head, middle and tail end. After inflow and out flow of each reach were estimated. The conveyance efficiency of canal was been the ratio of the amount of water delivered at the turnouts of the main irrigation conveyance network to the total amount of water diverted into the irrigation scheme (Small & Rimal, 1996). For each location conveyance efficiency (Ec) was calculated using following (equation 3.3).

$$E_C = \frac{V_d}{V_c} * 100 ---------------------3.12$$

Where, $E_c$ is the conveyance efficiency (%)

$V_d$ is water flowing ($m^3$/Sec) out of the section.

$V_c$ is water flowing ($m^3$/Sec) into the canal section.

The conveyance efficiency of water transporting canals into the field is mainly depends on the length of the canals, the soil type, permeability of the canal banks and the condition of the canals. According to Brouwer and Prins (1989) the conveyance efficiency for long unlined canals (> 2000 m), the conveyance efficiency have been reported as 60, 70, 80% for sand, loam, and clay soil respectively; for medium length unlined canals (200-2000) as 70, 75, 85% for sand, loam and clay soil respectively; and for short canals (< 200 m) as 80, 85 and 90% for sand, loam and clay soil respectively. The efficiency of lined canals has been reported as 95% for all canal length.

*B) Application Efficiency (Ea)*

Application efficiency has been common measure of relative irrigation losses and this definition is valid for all situations and all irrigation methods. Losses from the field occur as deep percolation and as field tail water or runoff and reduce the application efficiency. To compute Ea it is necessary to identify at least one of these losses as well as the amount of water stored in the root zone. This implies that the difference between the total amount of root zone storage capacity at the time of irrigation and the actual water stored due to irrigation be separated, i.e., the amount of under irrigation in the soil profile must be determined as well as the losses (FAO, 1989).

The evaluation of application efficiency was made on three selected fields i.e., from head, middle and tail reaches. The criteria for selection of field location were (upstream, middle, and tail), their similarity with water management practices and willingness of the farmers to collaborate. Then the soil sample was taken from the selected fields and water applied also measured at the inlet of the field by floating method at straight field furrow ditches were selected for accurate measurement.

The depth of water stored in the root zone of selected field was determined from the soil moisture content before and two days after irrigation by gravimetric method, Finally the application efficiency for the head, middle and tail end users of the irrigation schemes were been the ratio of the average depth of irrigation water stored in the root zone for crop consumptive use to the average depth of water applied (FAO, 1989):

$$E_a = \frac{\text{water stored in root zone (Zr)}}{\text{water received at field inlet}} ------------------- 3.13$$

Where $E_a$ is Application efficiency (%)

Zr is Depth of water in root zone (mm)

The depth of water retained in the soil profile in the root zone was determined using equation given by Mishra and Ahmad (1990) as:

$$z_r = \sum_{i=0}^{n} \left(\frac{\theta_{AI} - \theta_{BI}}{100}\ i * D\right) ---------------------- 3.14$$

Where $\theta_{AI}$ and $\theta_{BI}$ are moisture content of the $i^{th}$ soil compartments after and before irrigation on the oven dry volume basis (%), respectively; D is thickness of $i^{th}$ soil compartments and n is number of compartments in the root zone.

The (Ea) mainly depends on the irrigation method and the level of farmer discipline. Some indicative values of the average (Ea ) are 50-60%, 60-80% and more than 80% for surface, sprinkler and drip irrigation methods respectively (FAO, 1989).

*C) Scheme Efficiency ($E_S$)*

The most common way to express the efficiency of irrigation systems is to subdivide it into conveyance and application efficiencies. Once the overall conveyance and field application efficiency was determined, the scheme efficiency (Es) can be calculated, using the following equation (FAO, 1989):

$$E_S = Ec * Ea \text{ --------------------------- } 3.15$$

Where $E_s$ is scheme efficiency (%)

$E_c$ is main canal and distribution canals conveyance efficiency (%)

$E_a$ is application efficiency (%).

In small scale irrigation schemes secondary canals can be classified in distribution canal and can be designed as continuous or rotation based on the system (FAO, 1989). In this study in order to determine scheme efficiency (Es) the conveyance efficiency of main canal and secondary (distribution) canals were considered. The distribution canal efficiency was determined up to inlet of the fields.

### 3.5.2 Comparative Performance Indicators

Three groups of relevant comparative performance indicators were used in this study to assess and compare the performance of the two communities managed irrigation schemes. These are water supply, agricultural output and physical sustainability indicators. Under each group, relevant performance indicators were identified and used for comparative assessment (Dejen et al. (2012). However, in this study the output per unit water supply was not considered. Because of it is important when irrigation scheme with different rainfalls. The outputs of agricultural production were based on local prices.

*A) Water Supply Indicators*

The water supply indicators are based on irrigation and water supply/delivery measurements being related to demands or supply (Bos, 1994). Two indicators were considered under this group i.e. annual relative water supply (ARWS) and annual relative irrigation supply (ARIS) were evaluated for the agricultural year of 2016/2017 for each irrigation scheme.

- Annual relative water supply

This is the ratio of total seasonal/annual water supplied (irrigation plus rainfall) to the seasonal /annual crop water demand. This indicator signifies whether the water supply is in short or in excess of demand (Dejen et al., 2012):

$$\mathrm{ARWS} = \frac{\text{Total water supply}}{\text{crop water demand}} ---------------------3.16$$

Where, ARWS is annual relative water supply.

- Annual relative irrigation supply

This is the ratio of annual irrigation supply to annual irrigation demand. Irrigation water is a scarce resource in many irrigation schemes and is a major constraint for production. This indicator is useful to assess the degree of irrigation water stress/abundance in relation to irrigation demand (Dejen et al., 2012):

$$\mathrm{ARIS} = \frac{\text{Irrigation supply}}{\text{irrigattion demand}} --------------------3.17$$

Where, ARIS is annual relative irrigation supply.

RIS relates supply to demand, and shows some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched. 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 that is neither surplus nor deficit. Molden et al. (1998) recommended that most of the time it is better to have a RIS near one than a higher or lower value. When irrigation tightly fills the gap of water requirements after they are met by rain, RIS is near unity. Molden et al. (1998) investigated varying values of RIS indicators values 0.41 to 4.81, from 18 different irrigation schemes in the world.

Similarly for RWS, if the value is greater than one, it indicates water supply is beyond the water demand; if it is less than one, the water supply is below the water demand. While if it is equal to one, the supplied amount of water is sufficient to demand. Molden et al. (1998) investigated varying values of RWS indicators between 0.8 and 4, from 18 different irrigation schemes in the world.

*B) Agricultural Output Indicators*

The principle output of the scheme is the crop produce and the area irrigated. These need to be assessed seasonally or annually. The productivity can be indicated by measuring these outputs in gross terms or relative to input utilized. Agricultural output indicators can be subdivided into land productivity and water productivity (the ratio of physical quantity of crop production to the volume of water used) indicators (Small & Rimal, 1996). These external indicators provide the basis for comparison of irrigated agriculture performance (Molden et al., 1998).

1) Land productivity

- Output per unit irrigated cropped area (Birr/ha)

The output per unit irrigated cropped area (output per unit harvested area) quantifies the total value of agricultural production per unit of area harvested during the period of analysis. The annual harvested area depends on the intensity of cropping (Dejen et al., 2012). In this study the irrigated cropped area is the sum of all the areas under crops during the (2016/17) cropping year.

$$\text{OPUIA} = \frac{\text{Value of annual production}}{\text{Annual irrigated cropped area}} \left({}^{\text{Birr}}/_{\text{ha}}\right) --------------- 3.18$$

Where, OPUIA is output per unit irrigated cropped area.

- Output per unit command area (Birr/ha)

This is the value of agricultural production per unit of nominal area which can be irrigated or the size of land which could nominally be irrigated with the designed irrigation infrastructure. Smaller values of this indicator imply less intensive irrigation. It is particularly important where land is a constraining resource for production (Dejen et al., 2012):

$$\text{OPUCA} = \frac{\text{Value of production}}{\text{Nominal area}} \left({}^{\text{Birr}}/_{\text{ha}}\right) --------------- 3.19$$

Where, OPUICA is output per unit command area.

2) Water productivity

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

This tells on how well the total seasonal/annual diverted irrigation water from a source is productive. Irrigation water supply includes conveyance losses in canals. In areas where water is scarce, water management aims to increase the output per drop of irrigation water (Dejen et al., 2012):

$$\text{OPUIS} = \frac{\text{Value of annual production}}{\text{Diverted annual irrigation water}} \left(\text{Birr}/\text{m}^3\right) ------------3.20$$

Where, OPUIS is output per unit irrigation water supply or diverted.

- Output per unit irrigation water delivered (Birr/$m^3$)

This is meant for the value of production per unit volume of annual irrigation water delivered to the head of command area. It is different from irrigation supply as it does not include losses in conveyance systems. It is a useful comparative indicator because it addresses output per drop of irrigation water actually delivered to the user. Inefficient water use results in lower values of this indicator (Dejen et al., 2012):

$$\text{OPUID} = \frac{\text{Value of annual production}}{\text{Deliverd annual irrigation water}} \left(\text{Birr}/\text{m}^3\right) ---------- 3.21$$

Where, OPUID is output per unit irrigation water delivered.

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

This indicator informs on the output per unit annual volume of water consumed by actual evapo transpiration. Its value is highly dependent on climate. Moreover, less consumptive use coefficient due to water losses does not affect its value; as only the water consumptively used by the crops is considered. It is given as ((Dejen et al., 2012)):

$$\text{OPUWC} = \frac{\text{Anual value of production}}{\text{Water consumed by ET}} \left(\text{Birr}/\text{m}^3\right) --------3.22$$

Where, OPUWC is output per unit water consumed.

In this study the consumed water were determined by using FAO CROPWAT 8.0 version model

*C) Physical Performance (sustainability)*

This deals with the impact of both operational and agricultural inputs on the viability and sustainability of irrigated agriculture; these impacts include both physical and socio-economic sustainability of irrigated agriculture (Bos, 1994). Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. Two relevant performance indicators were considered under this group as was enumerated by (Şener et al., 2007).

- Irrigation ratio

This is the ratio of currently irrigated area to irrigable command (nominal) area. It tells the degree of utilization of the available command area for irrigated agriculture at a particular time. Irrigation ratio is expressed as:

$$\text{Irrigation ratio} = \frac{\text{Currently irrigated area}}{\text{Command (nominal) area}} \left({}^{\text{ha}}/_{\text{ha}}\right) ----------------3.23$$

- Sustainability of irrigated area

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

$$\text{Sustainabilty of irrigated area} = \frac{\text{Currently irrigated area}}{\text{Innitially irrigated area}} \left({}^{\text{ha}}/_{\text{ha}}\right) -------- 3.24$$

The three different area of land related to the schemes were collected to evaluate the physical indicators that are command area, initially irrigated land and currently irrigated land. The command area of each scheme was determined by locating the boundary of the main canal and drainage canal to take points using GPS. These points were then added to Arc GIS where the boundaries were plotted and the areas were determined. The initial irrigated areas when each scheme was taken from project reports and the same were confirmed from local irrigation agencies. Currently irrigated areas for each scheme, there is a list of irrigation water users along with their irrigated landholdings.

# 4 RESULTS AND DISCUSSIONS

## 4.1 Characterization of the Schemes

### 4.1.1 Current Condition of system structure

According to field survey the current condition of Mojo Asha scheme system structure was nearly damaged. The upstream of the weir is totally silted up by the flood during 2003, so that its water storage capacity is zero and right intake gate was buried by the silt with the weir body except the two guides and wing wall (Figure 4.1). The most of downstream parts of the diversion like wing walls, stilling basins, and riprap are also damaged. There are scouring effects under downstream part of the weir body.  This may be due to the fact that the system structure has no silt removal structure as well as the sluice gate. According to field observation, there are different types of control structures like off take, drops, chutes, division boxes, flume, culverts and turnouts.  But most of these structures were damaged partly or fully (figure 4.1).

The field survey revealed that Adano scheme, even though it is modern, it has no full system structures as it should have like sluice gate and stilling basins. This scheme has only one canal known as tarree canal and also some control structure like off take, drop, chutes, division boxes, etc. However most of these structures are not function at present (Figure 4.2).

Figure 4.1: Mojo Asha scheme head work and current condition of physical structures.

Figure 4.2: Adano scheme head work and current condition of physical structures.

4.1.2 Water management and distribution Practices

The local farmers of these schemes are mostly practicing irrigation traditionally. The indigenous method of irrigation application practiced in the area is unique. They use their own furrow dimension and method of application. Water management practices of the farmers are using furrows length between 10-20 meters and furrow spacing between 0.2-0.4 meters in Mojo Asha irrigation scheme. However, in Adano irrigation scheme farmers use wide furrow space more than 0.5-1 meters (figure 4.3). Mostly they apply water until the flow reach to the furrow end or overtop to the next furrow. However, sometimes they apply water until the field becomes flooded. Furrow constructing by spade (liso by local name) which is the equipment to open and close furrows while they are irrigating their crops. The location of plants in a furrow system is stand on top of the ridge in order to prevent damage as a result of water logging.

Figure 4.3: Farm's management practice of schemes.

The water uses and management practice in the schemes like elsewhere in woreda. The system is operating from late September or early October to end of April unless during the rain season. During rainy season (May to late August) main intake is closed until claim is made for irrigation water from the farmers in the scheme. According to the design note (2006), required amount of water per ha was estimated to be 1.1 l/s/ha at Mojo Asha and According to the design note (2008), required amount of water per ha was estimated to be 1 l/s/ha at Adano irrigation schemes. However during the study required amount of water per ha was estimated to be 0.73 and 0.84 l/s/ha at Mojo Asha and Adana irrigation schemes respectively. There are high gap between targets and actually implemented. According to information obtained from local user there are different canal diverted from Hamid River upstream of Mojo Asha irrigation scheme like Kabbar and Hamid canal. The much amount of water was diverted to these canals by users as you need. For this reason Hamid River at Mojo Asha irrigation scheme was reduced for long period of time. Generally, this indicates that during the planning and designing stage without consideration of upstream user influence on these schemes and also climatological variability on supply and demand.

Even if there are gap between targets and actually implemented of the required amount of water per ha. The total duration of irrigation being practiced in the schemes was 18 hours while the design duration is 12 hours during day time. This makes the value of dependability of duration to be 1.5 or 150 percent. They deliver water for more duration than designed. The farmers tend to compensate the poor irrigation scheduling and management problem with the prolonged water delivery.

The average irrigation intervals of the major crops of the schemes were 8 and 7 day at Mojo Asha and Adano irrigation schemes respectively. However the average designed irrigation interval was the same in both schemes which was 10 days. The dependability of irrigation schemes intervals is calculated by dividing the average irrigation interval of major crops of the schemes to the average designed interval of the schemes. It was 0.8 and 0.7 at Mojo Asha and Adano schemes respectively. This indicates that more frequently irrigate than intended. During the study there are no experiences of under irrigation by the farmers the chance of over irrigation is likely to resulting water wastage.

### 4.2 Crop and irrigation water requirement

The results of the evapotranspirtion and CWR for Mojo Asha and Adano schemes were presented in (Table 4.1). Water requirement of the crops were done for two growing seasons first from September to December and the second growing season from Januarys to April. This is done because of the water requirement of these seasons are different even for the same crop types. For detail results output of CROPWAT See Annex (Table A 1.17 -1. 31).

The total crop and irrigation water requirement at each schemes was estimated by taking input data of actual irrigated area by crop type.

Table 4.1: Total water demand of the first and second cropping season

| Irrigation Schemes | First Season | | | | Second Season | | | |
|---|---|---|---|---|---|---|---|---|
| | CWR (mm per season) | IWR (mm per season) | TRF (mm per season) | Eff RF (mm per season) | CWR (mm per season) | IWR (mm per season) | TRF (mm per season) | Eff RF (mm per season) |
| M/Asha | 461.7 | 316.2 | 164.8 | 152.1 | 479.9 | 254.1 | 287.1 | 235.4 |
| Adano | 451.1 | 303.7 | 176.7 | 160.4 | 486.8 | 255.8 | 296.4 | 242.1 |

From (Table 4.1) the crop water requirements of second season were higher than that of the first season, however lower irrigation water requirement than first season. Because of the monthly evapotranspiration of second season was higher than that of the first cropping season (figure 4.4).

### 4.3 Crop evapotranspiration (ETo)

The basic statistical data analysis of Girawa meteorological station shows that the mean monthly and annually reference crop evapotranspiration value was 3.92 mm and 1433 mm respectively. The minimum and maximum monthly ETo values were 3.65 mm/day in September and 4.35 mm/day in March. The mean monthly evapotranspiration of the location exceeds the total monthly rainfall amount except in May and August (figure 4.4). So, extra water is required to fulfill the evapotranspiration demands of the crop.

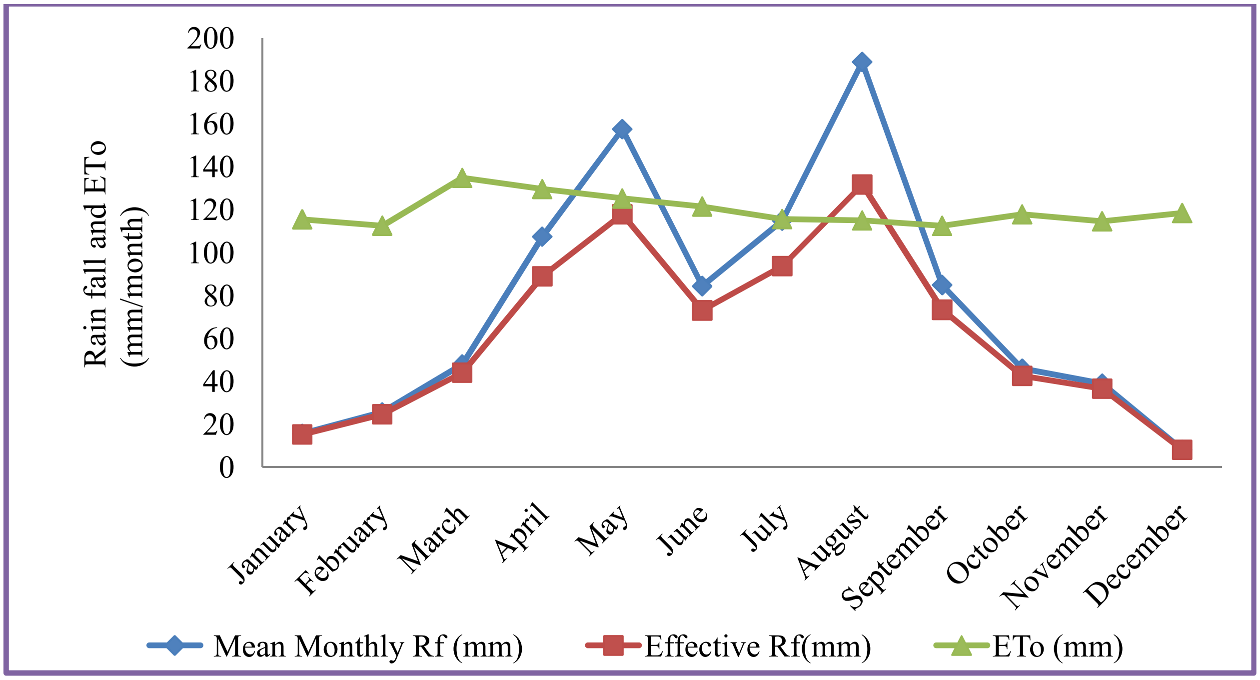


Figure 4.4: Mean monthly rainfall, effective rainfall and reference crop evapotranspiration in (mm/month).

### 4.4 Irrigation System Performance

4.4.1 Conveyance Efficiency ($E_C$)

The conveyance of the upper main canal (Head), middle main canal (Middle), and at end of main canal (Tail) was calculated (using equation 3.12). The results showed that wide range of variation between canal location upstream, middle and downstream (fig 4.5 and 4.6). This means high amount water losses present. The losses of irrigation water in the conveyance system can be a major component of the overall water losses, particularly for farms located at a distance from water sources where the main canals are long, unlined and aligned on hillsides.

The conveyance efficiency of Mojo Asha irrigation scheme measured at a distance of 0- 1500m was 57.58%. The amount of water lost in the main canal at a distance of 0- 500m, 500m-1000m and 1000-1500 m were 5.4 l/sec, 5.9 l/sec and 9.1 l/sec respectively. The conveyance efficiency of the Adano irrigation scheme measured at a distance of 0-1800m was 45.01%. The amount of water lost in the main canal at a distance of 0-600m, 600-1200m and 1200m-1800m were 29.38 l/sec, 14.35 l/sec and 16.79 l/sec respectively.

The results indicate that Adano schemes' canal losses higher than Mojo Asha scheme. The reason for this was leaking of the water where the canal was breached, heavily vegetated, and covered by high sediment load (See Annex Figure A 1.1, 1.2 and 1.3). The structures like drops, chute, off take and culverts are damaged partly or fully in the Adano irrigation scheme. Walker (1989) stated that control structures are necessary in the conveyance system to drop water to a lower elevation and to divide or divert the flow to the appropriate farm ditch.

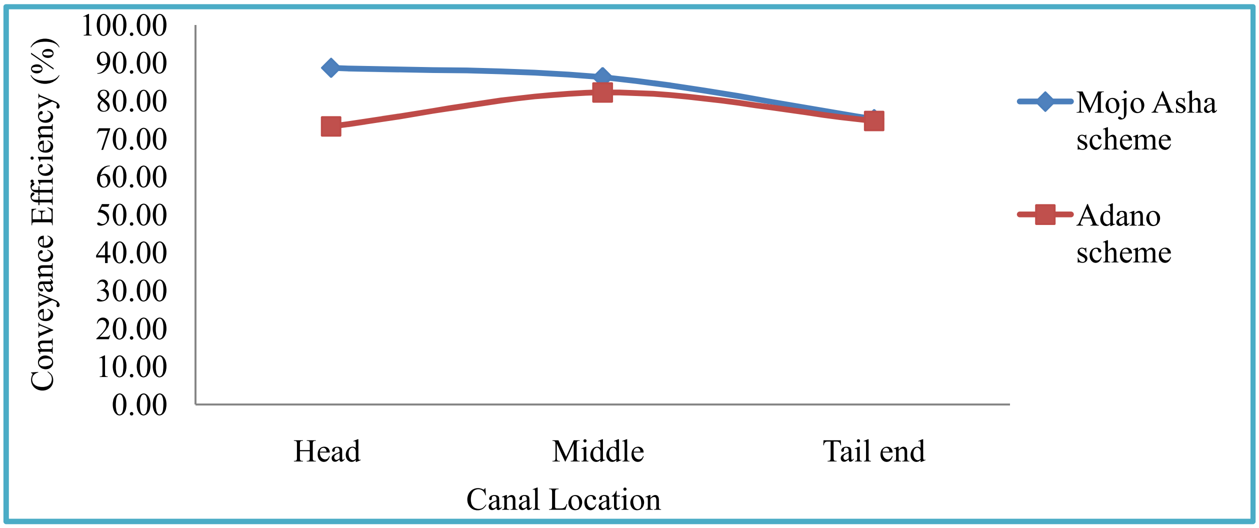


Figure 4.5: Main canal conveyance efficiency of schemes.

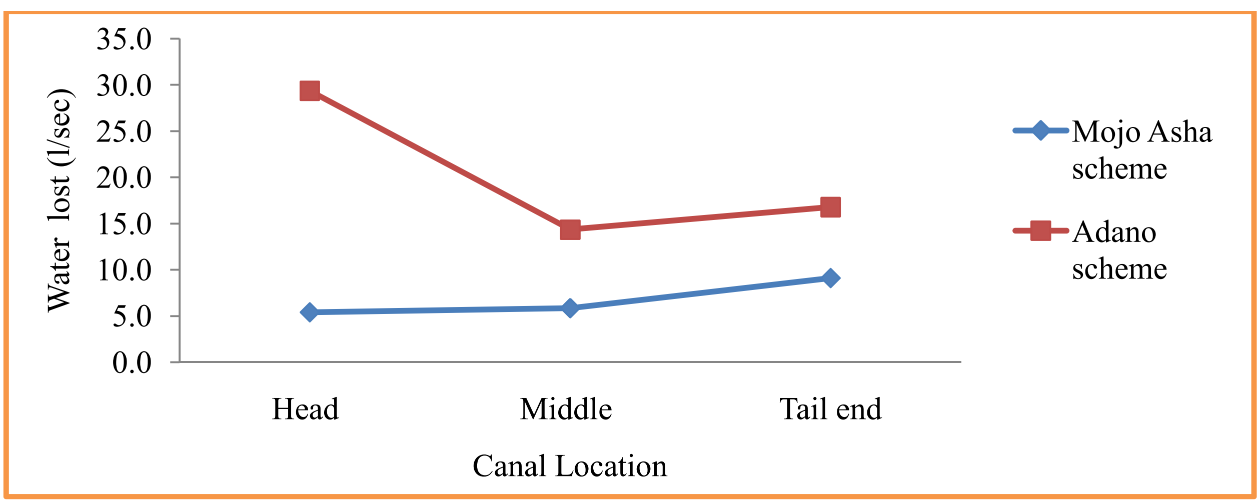


Figure 4.6: Main canal water lost of schemes.

*Main canal Cross-section*

In Mojo Asha irrigation scheme the shape of the main canal at middle and tail end was significantly changed from its original trapezoidal shape to parabolic and U shape. At these location width and depth becomes irregular as a result of sedimentation and deep vegetation effect. However the shape of the main canal at head was not changed significantly compared to its original design. In Adano irrigation scheme the shape of the main canal at head and tail end was significantly changed from its original shape. Its width became narrower and depth became shallower. So that changes of canal cross section was been the main reasons for poor conveyance (Fig. 4.7 and 4.8).

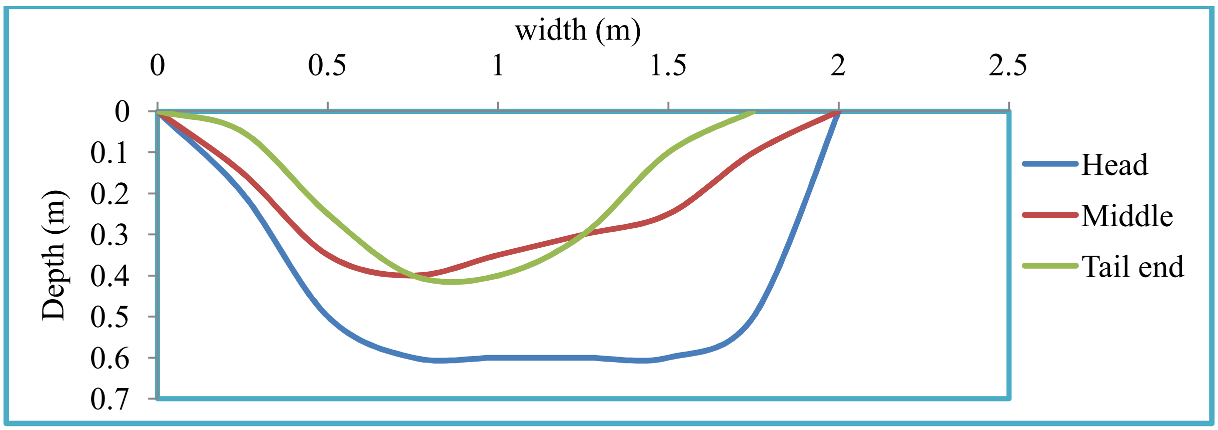


Figure 4.7: Mojo Asha irrigation schemes' main canal cross section.

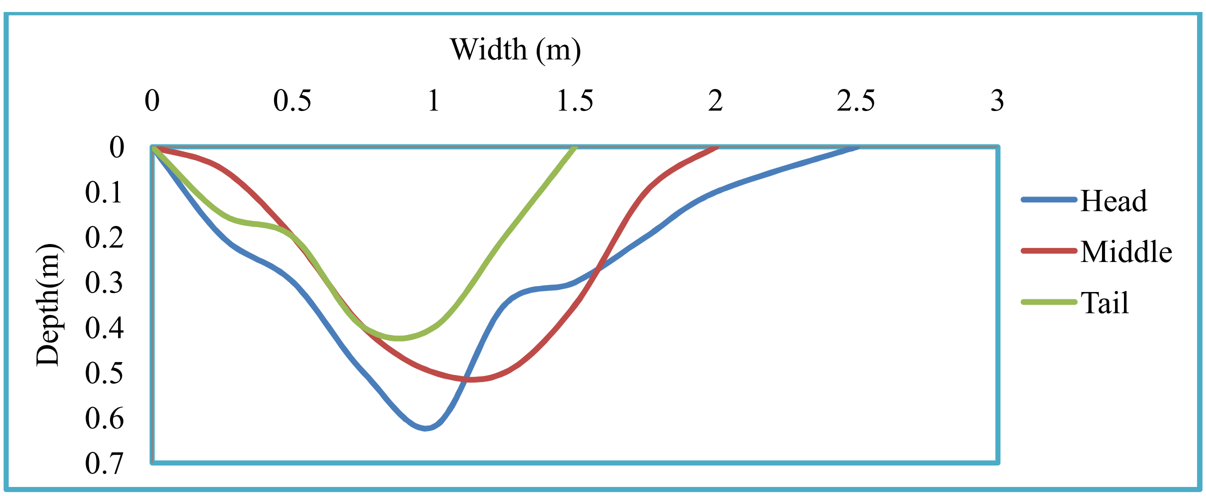


Figure 4.8: Adano irrigation schemes' main canal cross section.

*Secondary (distribution) canal conveyance efficiency*

It was very hard to find secondary and tertiary canals in irrigated fields as per the original design. As mentioned above, irrigators used to breach main and secondary canals during irrigation wherever he/she convenient. As a result, most of secondary and tertiary canals of the schemes are found ploughed and not to serving the downstream users. In this study Secondary (distribution) canal efficiency was estimated on three functional canals at a distance of 300m intervals. It was depends on locations of three farms fields which was selected from each schemes.

The results indicate that water loss in the field canal was higher than that of the main canal (Figure 4.9). Because the depth and width of the field canal was small for the amount of water diverted and overtopping was noted to be serious problem. The consumptive use by vegetation, leakage and losses were been main cause of low efficiency (See Annex Figure A 1.4 and 1.5).

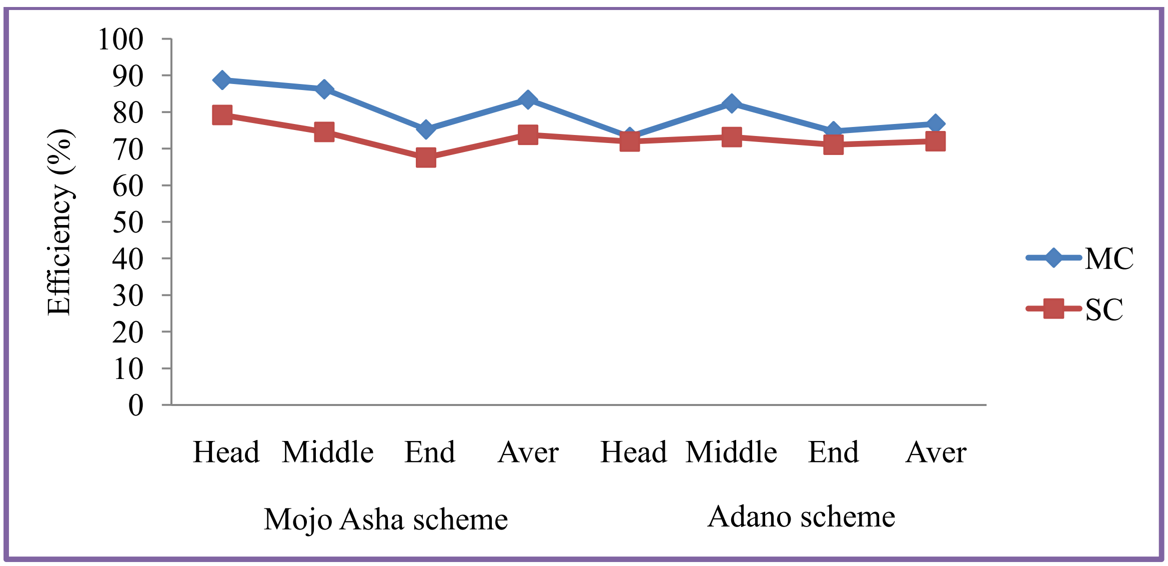


Figure 4.9: Main canal and secondary canal conveyance efficiency.

In generally, common problem in these schemes was the poor condition and inefficient way of water conveyance in the farm canal network. To improve the exploitation of the canal system it is important that farmers to understand the functioning of the canal system, the different problems that may occur in irrigation canals, their causes and how to avoid or overcome these problems.

4.4.2 Application efficiency (Ea)

When water is diverted into any water application system, part of the water infiltrates into the soil for consumptive use by the crop, while the rest is lost as deep percolation and runoff. The efficiency terms determine these components and compare them with the volume of water actually applied to the field. The term is an indication of the effectiveness of the system in reducing losses during an irrigation event.

In this study three farms fields were selected from each scheme to determine the performance of the schemes and to compare their efficiencies. These fields were selected at head, middle and tail end of water users of the irrigation project as discussed in previous section. The areas of selected fields from Mojo Asha irrigation scheme were 250m$^2$, 320m$^2$ and 340 m$^2$ from head, middle and downstream fields, respectively while from Adano scheme were 300m$^2$, 360m$^2$ and 350 m$^2$ from head, middle and downstream fields respectively.

The farm application efficiency of schemes at different farm was determined at head, middle and tail end to evaluate scheme performance using (equation 3.13). And also water applied for each farms were tabulated as following (Table 4.2).

Table 4.2: The selected fields and water applied to the field.

| | | Mojo Asha scheme | | | Adana Scheme | | |
|---|---|---|---|---|---|---|---|
| Selected Field | Field Location | Area (m$^2$) | Total Volume (m$^3$) | Applied Depth (mm) | Area (m$^2$) | Total Volume (m$^3$) | Applied Depth (mm) |
| Field I | From U/S | 250 | 24.2 | 96.9 | 300 | 40.5 | 135.1 |
| Field II | From M/S | 320 | 32.3 | 101.0 | 360 | 48 | 133.4 |
| Field III | From D/S | 340 | 32.6 | 95.8 | 350 | 37.3 | 106.7 |

U/S is upstream, M/S is middle stream and D/S is downstream.

The possibility of getting water for irrigation among irrigators in three field locations was quietly different. According to information obtained from local farmers indicated that the upstream irrigators were conditionally breach the main canal with small discharge without permission of "Malaka" and also frequently water applied to their field. Whereas, the middle and downstream had no access for such illegal diversion, they have only chance of waiting for their turn.

*Actual soil moisture storage*

The actual moisture stored in the soil was computed from the moisture content before and after irrigation. The actual moisture stored in the soil at 30 cm intervals down the profile was calculated using (equation 3.7 and 3.8) and presented in following (Table 4.3).

Table 4.3: The average results of soil moisture before and after irrigation.

| Schemes | Soil moisture % vol. | Field Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | U/S | | | M/S | | | D/S | | |
| | | 0-30 | 30-60 | 60-90 | 0-30 | 30-60 | 60-90 | 0-30 | 30-60 | 60-90 |
| Mojo Asha | $\theta_{BI}$ | 23.36 | 26.37 | 25.15 | 24.41 | 28.39 | 28.48 | 24.66 | 25.02 | 27.98 |
| | $\theta_{AI}$ | 30.57 | 32.20 | 28.53 | 32.79 | 33.86 | 32.86 | 34.03 | 31.31 | 33.21 |
| Adano | $\theta_{BI}$ | 23.17 | 26.68 | 26.35 | 24.00 | 24.12 | 28.42 | 26.70 | 29.95 | 26.67 |
| | $\theta_{AI}$ | 31.22 | 31.16 | 30.94 | 30.28 | 31.37 | 34.11 | 34.51 | 36.30 | 32.80 |

U/S is upstream, M/S is middle stream and D/S is down stream

The actual moisture stored in the soil which was evaluated two days after irrigation shows that much amount of water was stored in the upper 30 cm soil depth. It was decreases as one goes down from the surface in the soil depth. The depth of water stored was greater than depth of water required so that there are over irrigated. However, relatively less water depth was stored in the root zone for upstream fields than the other (Figure 4.10 and 4.11). This might be due to the fact that relatively small depth of water was applied at time of irrigation for upstream fields but more frequently than others.

According to Jurriens et al. (2001) discussed on the average depth of water which was stored in the target root zone before irrigation (SMD) and average depth of water which was stored in root zone after irrigation (AMS). When the target zone is entirely filled, AMS will equal SMD. If AMS < SMD, then there is under-irrigation and if AMS > SMD, then there is deep-percolation.

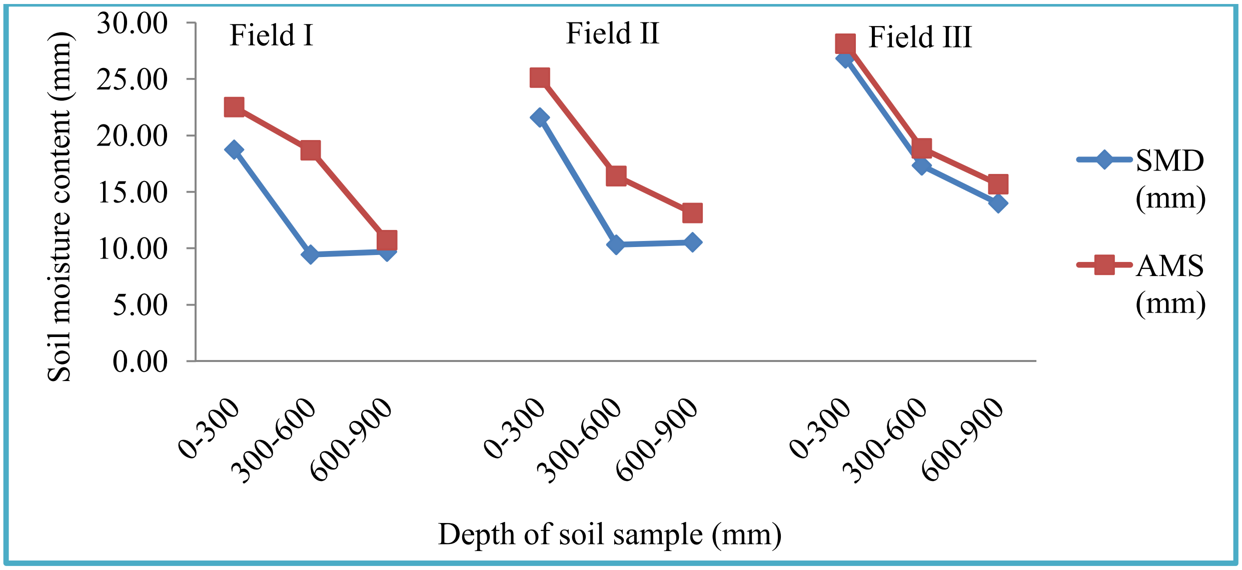


Figure 4.10: Actual moisture storage and soil moisture depletion of Mojo Asha scheme.

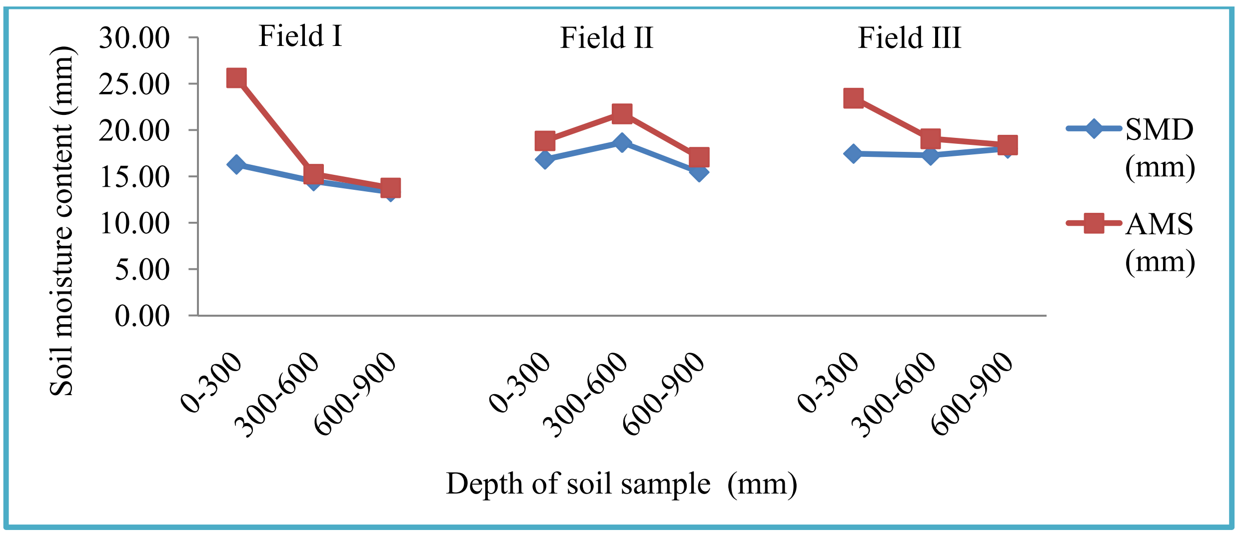


Figure 4.11: Actual moisture storage and soil moisture depletion of Adano scheme

Application efficiencies for each Scheme at different location were calculated from water applied and water stored in the root zone using equation (3.13) and results presented in (Table 4.4). The application efficiencies of Mojo Asha irrigation scheme for the three fields were 53.61%, 54.14% and 65.43% for upper, middle and downstream fields respectively while the application efficiencies of Adano scheme for three fields were 40.45%, 43.23% and 57.09% for upper, middle and downstream fields respectively.

Table 4.4: The application efficiency (Ea) of irrigation schemes

| Selected Field | Field Location | Mojo Asha Scheme | | | Adana Scheme | | |
|---|---|---|---|---|---|---|---|
| | | WAD (mm) | AMS (mm) | Ea (%) | WAD (mm) | AMS (mm) | Ea (%) |
| Field I | From U/S | 96.90 | 51.95 | 53.61 | 135.10 | 54.65 | 40.45 |
| Field II | From M/S | 101.00 | 54.68 | 54.14 | 133.41 | 57.67 | 43.23 |
| Field III | From D/S | 95.80 | 62.68 | 65.43 | 106.70 | 60.91 | 57.09 |

WAD: water applied to the field, AMS: actual soil moisture stored in the root zone, Ea: application efficiency.

The application efficiency was lowest at upstream field and highest at downstream field, this indicates that upstream user applying much amounts of water than demand in Mojo Asha and Adano irrigation scheme. But end users are more efficient than middle and head users. The farmers at the head of the system generally apply more water than needed for potential yield but it will reduce productivity of land and water while the tail end users were supply less amount water to their field (Gorantiwar and Kalu et al., 1995). This indicate that those irrigators who are getting less access water, were able to efficiently utilize which you have got even if their uniformity was poor.

4.4.3 Scheme Efficiency (Es)

After main canal and secondary or distribution canal efficiency and field application efficiency were determined the schemes efficiency was calculated using equation (3.15). The scheme efficiency of Mojo Asha and Adano irrigation schemes were 35.4 % and 25.9 % respectively. The result indicates that Mojo Asha scheme was performing better than Adano schemes. This may be due to that Mojo Asha irrigation scheme has more control structure than Adano irrigation schemes. The Adano scheme has some control structure and much amount of water was losing by seepage and over topping. And also unwise uses of water on the field was been the major problem of this scheme. According to FAO (1989) the scheme efficiency greater than 50% it was considered to be good while the scheme irrigation efficiency is less it was considered to be poor. Generally, the values of scheme efficiency of schemes were less than 50%, these indicated that the schemes are in need of rehabilitation and upgrade its performance.

## 4.5 Comparative Performance Indicators

### 4.5.1 Water supply Indicators

For water supply there are two indicators, i.e., ARWS and ARIS, were used as parameters to evaluate and characterize the performance of irrigation schemes separately and used to seen the variation of the indicators spatially.

*Water diverted to field*

Water diverted per season was calculated from canal discharge considering irrigation hour per day practicing in the area. The irrigation hour considered in the design document are 12 hours, but farmers in both schemes practicing average 18 hour for eight months of two irrigation seasons. Therefore, annual irrigation water diverted for two seasons was estimated to be 746,496 $m^3$ and 1,710,720 $m^3$ for Mojo Asha and Adano irrigation schemes respectively.

The amount of water diverted during the two seasons for each schemes were calculated as volume of water diverted divided by total irrigated area. The crops water requirement of two irrigation seasons were added and presented as the following (Table 4.5).

Table 4.5: The water supply and total water demand of the 2016/17 cropping year.

| S. NO | Irrigation Schemes | Irrigated Area in (ha) | Scheme Discharge (l/s) | CWR (mm) | IWR (mm) | TRF (mm) | ERF (mm) | Water diverted (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | Mojo Asha | 116.5 | 48 | 941.62 | 570.37 | 451.91 | 387.48 | 640.7 |
| 2 | Adano | 240 | 110 | 937.9 | 559.57 | 473.06 | 402.47 | 712.8 |

Water supply indicators for Mojo Asha and Adano irrigation schemes were calculated using (equation 3.16 & 3.17). The RWS were 1.09 and 1.19 at Mojo Asha and Adano schemes respectively. The RIS were 1.12 and 1.27 at Mojo Asha and Adano schemes respectively. It can be observed that RIS values are greater than RWS values for each scheme, which indicates that irrigation is the major source of water supply for agriculture in the area. See Summary of results for both schemes (figure 4.12)

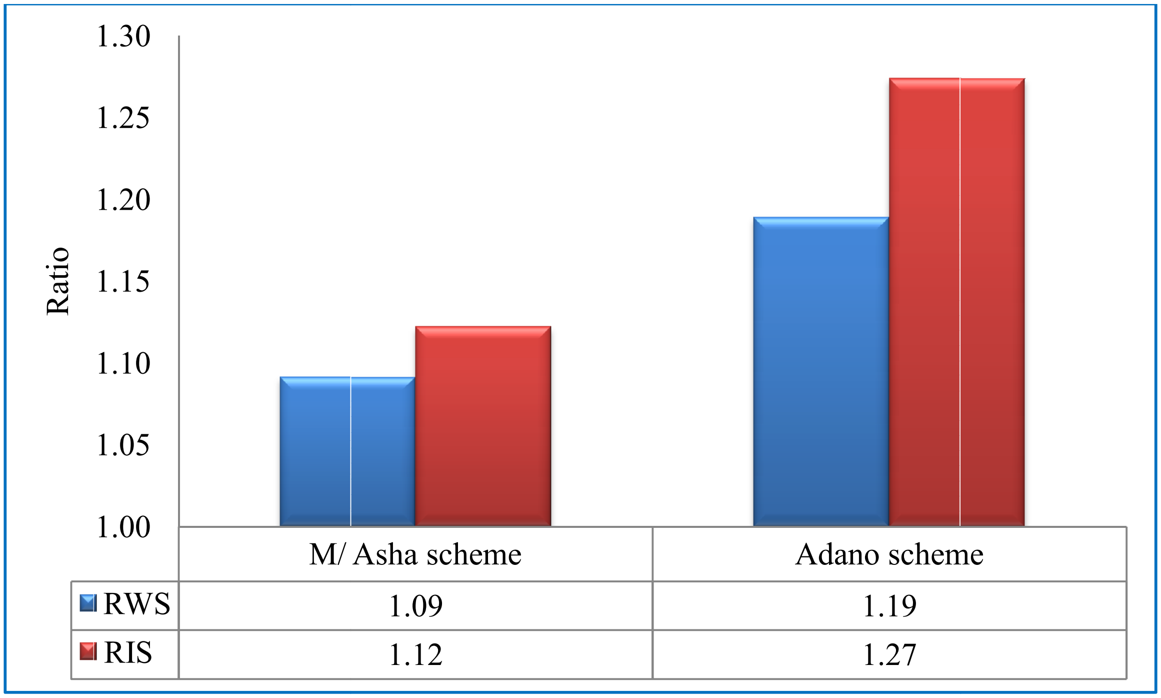


Figure 4.12: Water supply indicators

It can also be observed that there were a possibility to irrigate more command at Mojo Asha and Adano since ARWS and ARIS have been greater than 1(one). But the ARWS and ARIS are high in case of Adano scheme, implying that the excess irrigation water was being supplied much more than demand. The annual relative irrigation supply and annual relative water supply values are high because of the farmers open a canal before the rain was stopped and irrigate after the rain was started. These values should have minimized by using a real-time monitoring rainfall and adjusting the irrigation release from diversion structures to effectively use the rainfall component of the water supply. Although actually it is difficult to adjust unless create farmers awareness of water management practice.

### 4.5.2 Agricultural output

For the 2016/2017 cropping season the total production of Mojo Asha irrigation project was 6812 qt. This was planted on 116.5 ha and net command areas generating gross income of 6,435,150.00 birr. The prices of the crops were fluctuating time to time, so in order to avoid over or under estimation average values were considered. The total yields and land coverage of main crops of the two irrigation projects for the cropping seasons of 2016/2017 year were tabulated in (Table 4.6).

Table 4.6: Annual irrigation/water supply and Annual output of (2016/2017) irrigation year

| Schemes | Command area in (ha) | Irrigated Cropped area in (ha) | Irrigation water supply ($m^3$) | Irrigation water delivered ($m^3$) | Water consumed ($m^3$) | Output of 2016/17 irrigation season in (Birr) |
|---|---|---|---|---|---|---|
| M/Asha | 75 | 116.5 | 746,496 | 597,196 | 616,761 | 6,435,150.00 |
| Adano | 140 | 240 | 1,710,720 | 1,368,576 | 1,219,270 | 13,545,000.00 |

*A) Land productivity*

Land productivity for Mojo Asha and Adano irrigation schemes were calculated using equation (3.18 & 3.19). The results of land productivity indicated that the output per unit command is higher than output per unit irrigated area for each scheme, implying that the irrigation intensity at each scheme is higher than one. It also indicated that the output per unit command and output per unit irrigated cropped area was high in case of Adano Scheme. So, it is evident that there is more intensive irrigation at Adano thereby increasing the annual irrigated area in relation to the nominal command area. Therefore, Adano scheme is more productive comparatively (Figure 4.13).

*B) Water productivity*

Water productivity for Mojo Asha and Adano irrigation schemes were calculated using equation (3.20, 3.21 & 3.22). The results of water productivity indicated that the output per unit water consumed (OPUWC) at Adano scheme was much higher than Mojo Asha scheme. Adano Scheme, it apparently implies that the volume of water consumed by ET is much less than the irrigation diverted /water supplies and also indicates excess water/irrigation supply.

The output per unit irrigation water diverted/supplied (OPUIS) and output per unit irrigation water delivered (OPUID) values of Mojo Asha scheme was much higher than the corresponding values of Adano scheme. It implies that the value of irrigation water is higher at Mojo Asha implying more productive use of irrigation water than Adano Scheme. The lower values of OPUIS and OPUID indicators at Adano scheme could be attributed to water losses in conveyance, distribution and field application for example using wide furrow. However, output per unit water consumed (OPUWC) is not affected by water losses. This is due to the consumed water is actually used by ET of the crops (Figure 4.14).

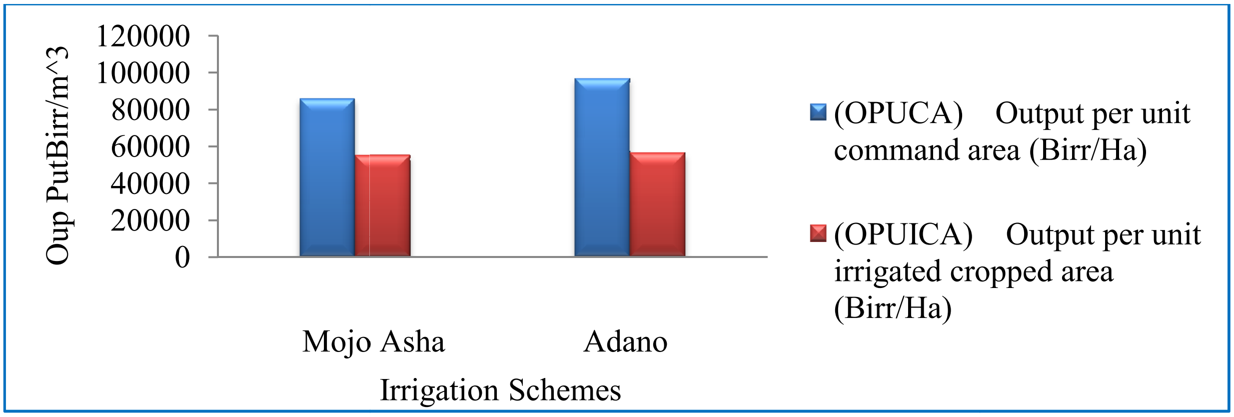


Figure 4.13: Irrigation scheme Land productivity.


Figure 4.14: Irrigation scheme Water productivity.

### 4.5.3 Physical Sustainability of irrigation schemes

Physical Sustainability of irrigation schemes for Mojo Asha and Adano irrigation schemes were calculated using (equation 3.23 & 3.24). The results indicated that the irrigation ratio is higher at Adano Scheme with a value of 0.92 implying 92% of the irrigable command area is currently under irrigation. Greater irrigation ratio at Adano could be explained by two factors, namely, generous water availability and better land productivity encouraging farmers to invest on more areas. Lower irrigation ratio at Mojo Asha scheme is attributed to lower reliability of irrigation flows during some months of the year and relatively lower land productivity compared to Adano Scheme (Figure 4.15).

Sustainability of irrigated area which tells at whether the area under irrigation is contracting or expanding. In Mojo Asha scheme, at the initial use of this scheme, the diversion was used to 75 ha of land. However, after right canal was failure due to gate was blocked by flood occurred before 5 years. The right canal is currently not functional due to this reason the area under this canal 9.5 ha of the land is not function. Therefore the irrigated area under this scheme is currently only 65.5 ha. The sustainability of irrigated area was 87 percent, implying reduction of irrigated areas by 13%. However, Irrigated area of Adano scheme was expanded by 10% (Figure 4.15). The same reasons for irrigation ratio like, more reliability of irrigation water flow and better land productivity are the contributing factors for the expansion.

Table 4.7: The different area of the land related to irrigation schemes

| Schemes | Command area in (ha) | Initial irrigated area (ha) | Currently irrigated area (ha) |
|---|---|---|---|
| Mojo Asha | 75 | 75 | 65.5 |
| Adano | 140 | 120 | 130 |

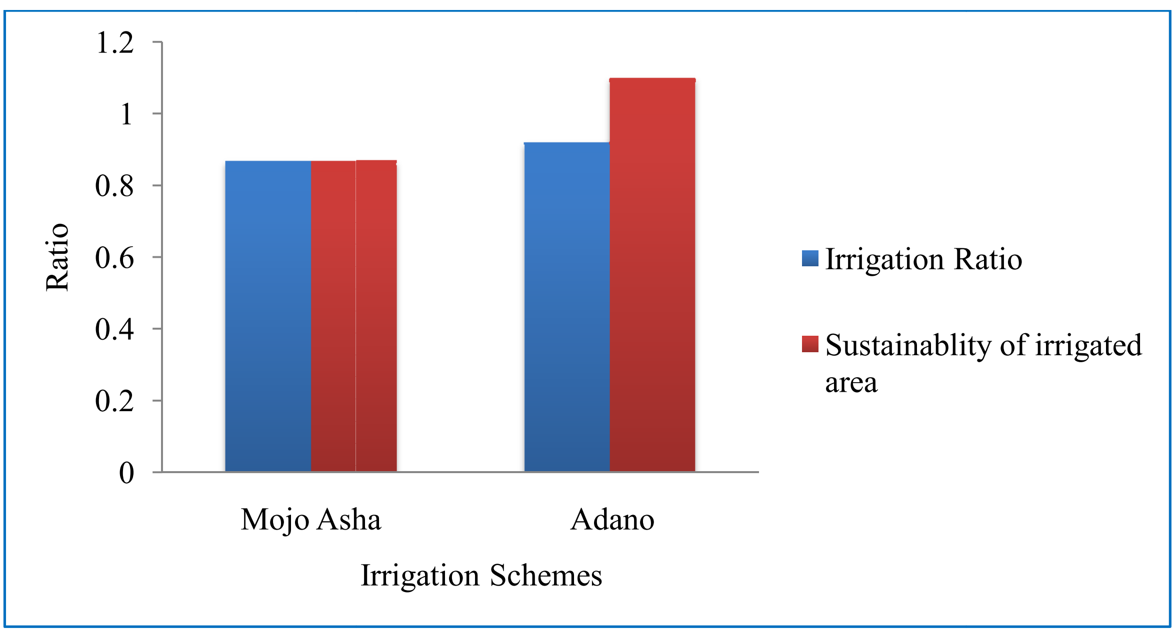


Figure 4.15: Physical Sustainability of irrigation schemes

# 5 CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

The irrigation schemes evaluation gives an indication of how these irrigation schemes are different in their irrigation system performance, operation, management, and productivity of land and water. The intention of the evaluation was to investigate how the performances of the irrigation schemes were consistent with respect to the irrigation practice; factors affect performance and improvement measures.

In system performance the conveyance efficiency of schemes was evaluated for each scheme at different reach or location. The results indicate that the maximum value of conveyance efficiency was found at upstream stream of Mojo Asha scheme to be 88.74 % and the minimum value was found at downstream of Adano scheme to be 73.34 %. The average conveyance efficiencies of Mojo Asha and Adano schemes were 83.41 % and 76.78 % respectively. The conveyance efficiency at the tail end is much less compared to head and middle system level in Mojo Asha scheme because of no frequent canal maintenance and sediment clearance at tail end system level where a shortage of canal water in this location. In Adano irrigation scheme the conveyance efficiency at the head end is much less as compared to middle and tail system level at this location canal structure deterioration, overtopping, seepage and canal losses due to almost of control structure was damaged. During field survey the observation reveal that the factors which affect canal efficiency are canal structure deterioration, long earthen canal, overtopping, and seepage.

In order to evaluate the irrigation water use efficiency of farmers at field level three farmers were selected from each irrigation projects in relation to their location (from the head, middle and tail end water users). The results indicate that the maximum value of application efficiency was found in downstream field of Mojo Asha scheme was 65.43% and the minimum value was found in the Adano scheme at upstream field 40.45%. This indicate that those irrigators who are getting less access water, were able to efficiently utilize what they have got even if their uniformity was poor. The application efficiency is mainly related to the management of water at field level, and the finding indicates that the downstream irrigators were the most efficient in applying water to their fields as compared to the upstream and middle irrigators.

From the analyses of the water performance indicators, both relative water supply and irrigation supply was greater than 1 at Mojo Asha and Adano schemes. The result of the ratios of RWS and RIS were 1.09 and 1.19 for Mojo Asha while 1.12 and 1.27 for Adano irrigation schemes, respectively. This indicated that irrigation water is not a constraint (over supply of water). The ratios of RWS and RIS at Adano scheme was higher than Mojo Asha scheme this means better practice of water management in Mojo Asha scheme. Water use practice of the farmer oversupply to irrigate the farm is mostly happen at upstream of the system and frequency of irrigation is also higher than tail end system. Due to the unwise use of water by the head end users; the tail end user faced water shortages frequently almost in both schemes.

From the analyses agricultural output indicators, output per unit irrigated water supply were 8.62 and 7.92 Birr/$m^3$ for Mojo Asha and Adano scheme respectively, output per unit irrigation water delivered were 10.78 and 9.90 Birr/$m^3$ at Mojo Asha and Adano scheme respectively while output per unit water consumed were 10.43 and 11.11 Birr/$m^3$ at Mojo Asha and Adano scheme respectively. Output per unit command area was been 85202 and 96750 Birr/Ha at Mojo Asha and Adano scheme respectively while Output per unit irrigated cropped area was been 55237 and 56437.5 Birr/Ha at Mojo Asha and Adano scheme respectively. The result indicates that output per unit irrigation/water supply were higher in case of Mojo Asha than Adano Scheme. This implies water productivity is higher at Mojo Asha scheme. However land productivity indicates more production yield in Adano scheme and also implies high value crop intensity increase output. So the scheme is productive comparatively. Generally land and water productivity in these schemes are much lower than other schemes such as Arara, Woter-02 and Hajifaja, but higher than Batu Dagaga and Doni irrigation schemes in Ethiopia.

Expansions or contractions of irrigated areas are also attributed to water management responsibilities and reliability of irrigation water supply. Irrigation ratio as a physical indicator showed that more areas of the command are irrigated when irrigation water supply is reliable as had been depicted at Adano Scheme. This was confirmed by expansion of area at Adano by 10%. The reasons for expansion at Adano are excess availability of water driving more farmers into the area. Generally, the values of overall schemes efficiency were considered to be poor. However the evaluation result of different indicators gives information of performance level of the schemes that enables to transfer best practice to propose improvement measures.

## 5.2 Recommendations

During field study irrigation schemes were observed that getting deterioration in its system structures need rehabilitation to its full, productive capacity of irrigable area. Maintaining of intake and sluice gate, canal lining, excavating and compacting earthen canal with selected materials, adoption of good water management practice (water distribution), system structure rehabilitation and modification are some improvement measures that can increase conveyance efficiency. These should be improved to achieve good performance.

As shown in discussion part the depths of water stored was greater than depth of water required in Mojo Asha and Adano schemes so that on-farm water application should have improve preparing common farm plans that could be the basis for preparing common irrigation schedules for groups of farmers. This prevents the tendency of the farmers to over irrigate the fields at each irrigation turn. The annual relative irrigation supply and annual relative water supply values are high in these schemes because of the farmers open a canal before the rain was stopped and irrigate after the rain was started. These values should have minimized by using a real-time monitoring rainfall and adjusting the irrigation release from diversion structures to effectively use the rainfall component of the water supply.

The farmers should have to improve the irrigation schedules in order to meet crop water demands at peak requirement and also crop diversification is necessary for more productivity of land. Every beneficiary in Mojo Asha and Adano irrigation schemes should have aware of the importance of water to their crops. They seem to lack the essential know-how on water requirements, correct intervals, more efficient application methods and the dangers of over watering. Consequently, improper water utilization patterns have become almost the rule resulting in wastage and land deterioration.

Outputs values were lower than that of the other research results in Ethiopia as presented in section 2.6. In fact, average outputs value low due to cultivation of low value crops such as Maize and potato in a large amount of area in both irrigation schemes. Besides, tomato and onion has good output but it is taking high amount of water. So output per unit water is much lower than for the other crops. To increase output, crop-pattern should include industrial crops and increase crop intensity.

In Mojo Asha irrigation scheme the farmers were cropping the same crop more than two times on the same land, its results loss of land productivity. So, awareness of crop diversification is necessary for more productivity of their land.

East Hararghe zone and Girawa Woreda irrigation development office should have support, continuous flow up and evaluate to provide feedback information for the future planning of management and maintenance of these schemes. Training of the development agents and water user association is essential to building the local understanding, management capabilities and community responsiveness Water user association should have establish in both scheme. For better performance and management of the schemes' water use; Crop Water Requirements and Irrigation Scheduling were computed for schemes using CROPWAT 8.0 and the output files are put commendably in Annex.

Generally, Even if performance was poor Mojo Asha scheme has best practice in water productivity as compared to Adano scheme. Therefore Adano scheme should have learn from Mojo Asha scheme. However Adano scheme has best practice in case of land productivity than Mojo Asha scheme. Therefore Mojo Asha scheme should have learn from Adano scheme.

# 6 REFERENCES

Abdi, A. 2015. Comparative Assessment of Water Management Practices in Selected Small Scale Irrigation Schemes: Case Study of Woter-02, Arara and Hajifeja schemes in Oromia.

Abernethy, C.L. 1986. Performance Measurement in Canal Water management: A Discussion. ODI-IIMI Irrigation Management Network Paper 86/2d, pp. 25.

Allen R. G., Pereira L. S., Raes D and Smith M. 1998. Crop Evapotranspiration:-Guidelines for Computing Crop Water Requirements. Irrigation and Drainage Paper, 56. FAO, Rome.

Ali, M. H. 2011. Water Conveyance Loss and Designing Conveyance System. J. Practices of the Irrigation and On-farm Water Manag., 2: 1-34.

Arshad, M., N. Ahmad, M. Usman and A. Shabbir. 2009. Comparison of water losses between unlined and lined watercourse in Indus Basin of Pakistan. Pak. J. Agri.Sci. 46:280-284.

Awullachew, S. B., Lambisso, R., Asfaw, G., Yilma,A.D. and Moges S.A. (2010).Characterizing, Assessing of performance and causes of underperformance ofirrigation in Ethiopia. Ethiopian Journal Development Research.

Awulachew, S. B.; Yilma, A. D.; Loulseged, M.; Loiskandl, W., Ayana, M.; Alamirew, T. 2007.Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. 78p. (Working Paper 123).

Ayana and Awulachew, 2005, comparison of irrigation performance based on management and crop type, Ethiopia.

Blake, G.R., 1965. Bulk density, In: Black, C.A. (Ed.), Methods of Soil Analysis. American Society of Agronomy, Madison, WI.

Bos, M.G, Burton M.A and Molden D.J. 2005.Irrigation and Drainage Assessment Practical Guidelines. CABI publishing. Trowbridge, UK. www.cabi-publishing.org Accessed in February 2006.

Bos, M.G. 1997. Performance indicators for irrigation and drainage, Irrigation and Drainage systems.11:119-137.

Bos, M.G, Murray-Rust D.H, Merrey D.J., Johnson H.G. and Snellen W.B. 1994. Methodologies for Assessing Performance of Irrigation and Drainage Management. Irrigation and Drainage Systems, 7:231-261.

Brouwer, C. and K. Prins, 1989. Irrigation Water Management: Irrigation Scheduling. FAO. Rome.

Burt, C. M. and S. W. Styles, 1999. Modern Water Control and Management Practices in Irrigation: Impact on Performance. Water Reports No. 19. International Programme for Technology and Research in Irrigation and Drainage.The World Bank. FAO, Rome.

Dejen et al, 2012. Comparative irrigation performance assessment in community-managed schemes in Ethiopia. Available online at (http://www.academicjournals.org/AJAR)

Depeweg, H. 1999. off Farm Conveyance and Distribution Systems. Land and Water Engineering. CIGR Handbook of Agricultural Engineering. Volume I. America Society of Agricultural Engineers (ASAE). USA.

Douglas L. V., Juan A. S. 1999. Transfer of Irrigation Management Services. Guideline: Irrigation and Drainage Paper. No.58. FAO, Rome.

Ehui. S., Benin S., Williams T. and Meijer S., 2002. Food security in sub-Saharan Africa to 2020. ,Socio-economic and Policy Research Working paper 49. ILRI (International Livestock Research Center), Nairobi, Kenya. 2-3

Elias, A. 2011. Sustainability of small scale irrigation schemes: a case study of Nedhi Galan sedi small scale irrigation in Deder Woreda, Eastern Oromia. Thesis presented Addis Abeba University.

Fahong, W., Xuquing, W. and Sayre, K.D. 2003. Comparison study on two different planting methods for winter wheat in China. Bed planting course, CIMMYT, Mexico.

FAO (Food and Agriculture Organization), 1997. Small-Scale Irrigation For Arid Zones: Principles and Options. FAO, Rome..

FAO (Food and Agriculture Organization), 2006. Manual for participatory Rapid Diagnosis and Action Planning for Irrigated Agriculture. Rome. Italy.

FAO (Food and Agriculture Organization), 1995. Irrigation in Africa in Figures: FAO Water Reports No. 7. FAO, Rome Italy.

FAO (Food and Agriculture Organization), 1989. Guidelines for Designing and Evaluating Surface Irrigation System: Irrigation and Drainage Paper.No. 45. FAO, Rome Italy.

FDRE, 2010. Growth and Transformation Plan (GTP) 2010/11-2014/15 (Draft), Federal Democratic Republic of Ethiopia, Addis Ababa.

Garg, S. K. 1989. Irrigation Engineering and Hydraulic Structures. 8th edition. Khanna publishers, New Delhi.

Getahun, G. 2008. Performance Evaluation and Environmental Impact Assessment of Community based irrigation in the Awash basin.

Girawa Woreda Agricultural Development Office, 2016. Land use pattern.

Gorantiwar, S. D. 1995. A model for planning and operation of heterogeneous irrigation schemes in semi-arid regions under rotational water supply. Ph.D. Thesis, Loughborough University of Technology, Loughborough, Leicester shire, UK.

Gupta, R.K., Naresh, R.K., Hobbs, P.R., Jiaguo, Jheng and. Ladha, J.K. 2003. Sustainability of post-green revolution agriculture: The rice-wheat cropping systems of the Indo-Gangetic Plains and China. In: Improving the Productivity and Sustainability of Rice-Wheat Systems: Issues and Impact. (Eds., Ladha, J.K. Hill, J., Gupta, R.K., Duxbury, J. and Buresh. R.J.), pp.1-25, ASA, Special Publication 65. ASA, Madison.

Hundie, B. 2006, Performance Assessment and Benchmarking Irrigation Schemes: A Case Study of Two Irrigation Schemes, Ethiopia.

IWMI (International Water Management Institute), 2007. Ethiopia: Agricultural Water Management Policy Briefs.

James, L.G., 1988. Principles of Farm Irrigation Design. John Wiley and Sons, Inc. New York.

Jurriens M., D. Zerihun, J. Boonstra, and J. Feyen, 2001. SURDEV: Surface Irrigation Software. Publication 59, ILRI, Wageningen.

Jonish JE. 1991. Benefits and costs of laser land leveling in Egypt. In: Bishay A, Dregne H (eds) Desert development Part 1: desert agriculture, ecology and biology: Proceedings of the Second International Desert Development Conference held on 25–31 January 1987 in Cairo, Egypt, vol 4. Harwood, Switzerland, pp 6–9.

Kloezen W. H. and Garces-Restrepo C. 1998. Assessing Irrigation Performance with Comparative Indicators: The Case of the Alto Rio Lerma Irrigation District, Mexico. Research Report 22. International Water Management Institute. Colombo, Sri Lanka.

Leliso, I. (2008). Technical Performance Evaluation of Small-Scale Surface Irrigation System: The Case Of Woter, Oromia Region.

Makombe, G.; Namara, R.; Hagos, F.; Awulachew, S. B.; Ayana, M.; Bossio, D., (2011), A comparative analysis of the technical efficiency of rain-fed and smallholder irrigation in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. 37p. (IWMI Working Paper 143).

Malano, H., and Burton, M., 2001 “Guideline for Bench Marking Performance in the Irrigation and Drainage Sector”.

Malano H, Burton M, Makin I. 2004. Benchmarking performance in the irrigation and drainage sector: A tool for change. Irrig. Drain. 53:119–133.

Mallappa M and Radder GD. 1993. Evaluation of different proportion of leveling in Zingg conservation terraces on soil moisture conservation, crop growth and yield of green gram. Mysore J AgricSci 6(3):241–246

McIndoe, I; Edkins, R; Bloomer, D; Daveron, A. 2005. Irrigation efficiency gaps expectations. Aqualinc Research Report No. L 05264/1, prepared for MAF (Sustainable Farming Fund) and Irrigation New Zealand.

Mehta N. K. 1994. Irrigation Water Management for Bhadra Reservoir project. Water Report 2. Karnataka, India.

Mekuria T. 2003. Small- Scale Irrigation for Food Security in Sub-Sahara Africa Center for Agriculture and Rural Cooperation (CTA) working document number 8031: 2-3

Merriam, J. L., Shearer, M. N., and Burt, C. M. 1983. Evaluating Irrigation Systems and Practices In: Design and Operation of Farm Irrigation Systems. An ASAE Monograph No. 3, American Society of Agricultural Engineers Publisher, USA. pp 721-760.

Mishra, R.D. and M. Ahmad, 1990. Manual on Irrigation Agronomy. Oxford and IBM Publicating CO . PVT. LTD. New Delhi, Bombay, Calcutta.

Molden D.J, R. Skethivadivel, C.J. Perry and C. Fraiture. 1998. Indicators for comparing Irrigation Agricultural System, Research Report 20, Colombo, Srilanka: IWMI.

Molden, D.J. & Gates, T.K. 1990. Performance measures for evaluation of irrigation-water delivery systems .Journal of Irrigation and Drainage Engineering116 (6): 804–823.

MoA (Ministry of Agriculture) Natural Resources Management Directorates, (2011), Small-Scale Irrigation Situation Analysis and Capacity Needs Assessment, Addis Ababa, Ethiopia.

MoWR (Ministry of Water Resources), 2002. Water Sector Development Progamme 2002-2016, Volume II: Main Report. Ministry of Water Resources, Federal Democratic Republic of Ethiopia, Addis Ababa, October 2002.

Murray-Rust, D, H. and W.B. Snellen. 1993. Irrigation system performance assessment and diagnosis. Colombo, Sir Lanka. International Irrigation Management Institute. 20 + 148 pp.

Nijman, C.M. 1992. Performance evaluation and control in water delivery decision making processes: Who cares? Irrigation and Drainage Systems6: 85–112.

Oad, R. and Sampath R. K. 1995. Performance measure for improving irrigation management. Irrigation and Drainage Systems, 9:357-370.

OIDA (Oromia Irrigation Development Authority), 2006 Study and Design team, Mojo Asha Irrigation project, Design report, Harar.

OIDA (Oromia Irrigation Development Authority), 2008 Study and Design team, Adano Irrigation project, Design report, Harar.

OIDA (Oromia Irrigation Development Authority), 2013 Strategic Planning and Management Document, Finfine.

Ren WT, Hu ZF, Cui HG, Yang CT, Liu Y, Wang YJ, Zhang ZY, Li BF. 2003. Effect of laser controlled land leveling and baby rice seedling direct planting on saving water. Trans Chin Soc Agric Eng 19(3):72–75.

Renault D and Vehmeyer P. W. 1999. On reliability in irrigation service preliminary concepts and application. Irrigation and Drainage systems 13: 75 – 103.

Rickman, J.F. 2002. Manual for laser land leveling, Rice-wheat Consortium Technical Bulletin Series 5. New Delhi-12, India: Rice-wheat Consortium for the Indo-Gangetic Plains. pp.24.

Rose R. 1993. "Some Sustainability and Resource Policy Issues in ILCA'S Livestock Research in Sub-Saharan Africa", Proceeding of the Research Planning Workshop Held at ILCA, Addis Ababa.

Salman, M.; Burton, M.; Dakar, E. 1999. Improved irrigation water management, or drainage water reuse: a case study from the Euphrates basin, Syria.WCA info NET. Water Conservation and Use in Agriculture. Lausanne, Switzerland. URL: http://www.wca-infonet.org/id/1275. Accessed in June, 2004.

Sarwar, T., M. Jehangir and M.J. Khan. 2001. Effect of watercourse maintenance and variable discharges on conveyance losses and water distribution. SarhadJ.Agric. 17:387-394.

Small, L.E. and Svendsen, M. 1992. A framework for assessing irrigation performance. IFPRI Working Papers on Irrigation Performance No.1, International Food Policy Research Institute, Washington, D.C.

Small, L.E. & Rimal, A. 1996. Effects of alternative water distribution rules on irrigationsystems performance: A simulation analysis.Irrigation and Drainage System10: 25–45.

Smith, M. 1992. CROPWAT: A Computer Programme for Irrigation Planning and Management. Irrigation and Drainage paper No. 24. FAO, Rome

Şener M, Yüksel AN, Konukcu F (2007). Evaluation of Hayrabolu irrigation scheme in Turkey using comparetive performance indicators. J. Tekirdag Agric. Fac. pp. 1-4.

Tilahun H. and Paulos D. 2004. Results to Date and Future Plan of Research on Irrigation and Its Impact. Workshop on Impact of Irrigation on Poverty and Environment, Workshop Proceedings, 26 -30, April 2004, Addis Ababa, Ethiopia.

Van den Bosch B.E; Snellen W.B.; Brouer C. and Hatcho N. 1993. Structures for water control and distribution. Irrigation Water Management Training manual no. 8. FAO. Rome, Italy.

Vidhya, R.; Karmegam, M. and Venugopal K. 2002. Conference paper on GIS based diagnostic analysis of irrigation system performance assessment of Bhadra command area at disaggregated level. GIS Development.net. http://www.gisdevelopmen...002pf.htm. Accessed in September 2004.

Wahaj, R., 2005. Backstopping Note for Improvement Irrigation Efficiency in paddy fields in the Lower Mekong River Basin (IEPF)"), MRC and FAO cooperation, AIFP/OPD, Vientiane, Laos.

Walker,W.R. and G.V. Skorerboe, 1989. Surface Irrigation: Theory and Practice. Prentice Hall, Englewood Cliffs, New Jersey.

Walker, W.R. 1987. Guidelines for Designing and Evaluating Surface Irrigation Systems.FAO Irrigation and Drainage Paper 45.Food and Agriculture Organization of the United Nations. Rome, Italy.

World Bank, 2006. Ethiopia: Managing Water Resources to Maximize Sustainable growth, A World Bank Water Resources Assistance Strategy for Ethiopia, The World Bank Agriculture and Rural Development Department. Report No. 36000-ET Washington, DC, USA.

Yashima, S. 1997. Data Systematization for Assessing Irrigation performance: a case study of the Muda Irrigation Project on Water Utilization Performance. Rural and environmental Engineering No. 32 (1997) pp 42 – 61. International Irrigation Management Institute.

Yusuf, K. (2003). Assessment Of Small Scale Irrigation Using Comparative Performance Indicators On Some Selected Farms In Upper Awash River Valley.

# 7 ANNEX

## Annex Tables

Table A 1.1 Average monthly meteorological data of Girawa Station (1993-2016).

| Month | Max Temp ($^oC$) | Min Temp ($^oC$) | Mean Temp ($^oC$) | Mean RH (%) | Wind Speed. (Km/hrs) | Sunshine (hr) | RF In (mm) |
|---|---|---|---|---|---|---|---|
| January | 21.4 | 9.1 | 15.25 | 55.5 | 6.13 | 9.05 | 15.62 |
| February | 22.3 | 9.7 | 16 | 60.2 | 7.15 | 8.03 | 25.65 |
| March | 23.7 | 10.4 | 17.05 | 59.6 | 7.63 | 7.61 | 47.9 |
| April | 24.6 | 11.2 | 17.9 | 63.5 | 6.98 | 7.26 | 107.5 |
| May | 24.3 | 11.5 | 17.9 | 70.9 | 7.27 | 6.95 | 157.64 |
| June | 24.5 | 11.4 | 17.95 | 71.1 | 9.40 | 6.46 | 84.46 |
| July | 22.3 | 10.9 | 16.6 | 75.4 | 9.88 | 6.43 | 114.97 |
| August | 22.3 | 10.8 | 16.55 | 75.3 | 8.06 | 6.36 | 168.96 |
| September | 23.2 | 9.8 | 16.5 | 75.8 | 5.04 | 6.57 | 104.96 |
| October | 23.4 | 9.5 | 16.45 | 61.4 | 4.10 | 7.65 | 45.95 |
| November | 22.8 | 9.4 | 16.1 | 56.7 | 5.00 | 9.03 | 38.97 |
| December | 21.3 | 9 | 15.15 | 55.4 | 5.58 | 8.9 | 8.2 |
| Average | 23.01 | 10.23 | 16.62 | 65.07 | 6.85 | 7.53 | 76.70 |

Table A 1.2: Main canal average discharge of Mojo Asha scheme

| Canal location | Canal section | Aver depth (m) | Aver Width (m) | Area (m2) | Length (m) | Elapsed Time (s) | Velocity (m /sec) | Discharge (l/sec) |
|---|---|---|---|---|---|---|---|---|
| Head | At intake | 0.53 | 0.85 | 0.45 | 4.00 | 30.00 | 0.11 | 48.05 |
| Head | 0-500m | 0.52 | 0.83 | 0.43 | 4.00 | 30.50 | 0.10 | 45.28 |
| Middle | 500-1000m | 0.47 | 0.67 | 0.31 | 4.00 | 25.00 | 0.13 | 39.58 |
| End | 1000 -1500m | 0.39 | 0.47 | 0.18 | 4.00 | 18.00 | 0.18 | 32.17 |

Table A 1.3: Main canal average discharge of Adano scheme

| Canal location | Canal section | Aver depth (m) | Aver Width (m) | Area (m2) | Length (m) | Elapsed Time (s) | Velocity (l /sec) | Discharge (l/sec) |
|---|---|---|---|---|---|---|---|---|
| Head | At intake | 0.62 | 1.00 | 0.62 | 4.00 | 18.00 | 0.18 | 110.22 |
| Head | 0-800m | 0.60 | 0.90 | 0.54 | 4.00 | 18.50 | 0.18 | 93.40 |
| Middle | 800-1600m | 0.60 | 0.78 | 0.46 | 4.00 | 18.50 | 0.18 | 80.03 |
| End | 1600-2400m | 0.55 | 0.64 | 0.35 | 4.00 | 17.50 | 0.19 | 64.09 |

Table A 1.4: Main Canal Conveyance Efficiency of scheme

| Schemes | Canal location | Inflow (l/sec) | Out flow (l/sec) | Loss | | Conveyance efficiency (%) |
|---|---|---|---|---|---|---|
| | | | | (l/sec) | (l/sec/m) | |
| Mojo Asha | Head | 48.05 | 42.64 | 5.41 | 0.011 | 88.74 |
| | Middle | 42.64 | 36.78 | 5.86 | 0.012 | 86.26 |
| | End | 36.78 | 27.67 | 9.11 | 0.018 | 75.23 |
| | Over all main canal conveyance efficiency | | | | | 57.58 |
| Adano | Head | 110.22 | 80.74 | 29.48 | 0.049 | 73.25 |
| | Middle | 80.74 | 66.47 | 14.27 | 0.024 | 82.33 |
| | End | 66.47 | 49.69 | 16.78 | 0.028 | 74.76 |
| | Over all main canal conveyance efficiency | | | | | 45.10 |

Table A 1.5: Secondary canals conveyance efficiency of scheme

| Schemes | Canal location | Inflow (l/sec) | Out flow (l/sec) | Loss | | Conveyance efficiency (%) |
|---|---|---|---|---|---|---|
| | | | | (l/sec) | (l/sec/m) | |
| Mojo Asha | Head | 38.345 | 30.305 | 8.04 | 0.027 | 79.2 |
| | Middle | 27.455 | 20.555 | 6.9 | 0.023 | 74.54 |
| | End | 24.185 | 17.375 | 6.81 | 0.022 | 70.56 |
| | Over all secondary canal conveyance efficiency | | | | | 45.31 |
| Adano | Head | 73.895 | 53.12 | 20.8 | 0.07 | 71.9 |
| | Middle | 64.59 | 47.23 | 15.15 | 0.057 | 73.17 |
| | End | 52.265 | 32.49 | 20.775 | 0.069 | 61.08 |
| | Over all secondary canal conveyance efficiency | | | | | 43.97 |

**ANNEX: AGRICULTURAL PRODUCTION DATA**

Collected from (woreda Agricultural extension expert)

location of the project, PA Mojo Sade

project Name Mojo Asha Scheme

Average Family size_____6_____

Table A 1.6: Agricultural production of Mojo Asha scheme Yield in quintal

| S.NO | Crop type | Land in (ha) | | | | Yield in quintal | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2008 | 2009 | 2006 | 2007 | 2008 | 2009 |
| 1 | Tomato | 26 | 27.5 | 27.5 | 28.5 | 2300 | 2500 | 2550 | 2750 |
| 2 | Pepper | 16 | 15.5 | 15 | 13 | 1368 | 1278 | 1351 | 950 |
| 3 | Maize | 6 | 6 | 6.5 | 9 | 530 | 500 | 557.5 | 800 |
| 4 | Onion | 7.5 | 8 | 9.5 | 11.5 | 912 | 976 | 1150 | 1000 |
| 5 | potato | 3.5 | 2.5 | 2 | 2.5 | 641 | 581 | 551 | 200 |
| 6 | Cabbage | 2 | 1.5 | 1.5 | 1 | 80 | 70 | 55 | 40 |
| | Total | 61 | 61 | 62 | 65.5 | 5831 | 5905 | 6214.5 | 5740 |

Table A 1.7: Agricultural production of Mojo Asha Scheme current price per quintal

| S. NO | Crop type | Land in (ha) | | | | Current price per quintal | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2008 | 2009 | 2006 | 2007 | 2008 | 2009 |
| 1 | Tomato | 26 | 27.5 | 27.5 | 28.5 | 950 | 1000 | 1150 | 1200 |
| 2 | Pepper | 16 | 15.5 | 15 | 13 | 780 | 950 | 1200 | 1400 |
| 3 | Maize | 6 | 6 | 6.5 | 9 | 400 | 450 | 450 | 550 |
| 4 | Onion | 7.5 | 8 | 9.5 | 11.5 | 830 | 910 | 1100 | 1200 |
| 5 | potato | 3.5 | 2.5 | 2 | 2.5 | 420 | 450 | 500 | 735 |
| 6 | Cabbage | 2 | 1.5 | 1.5 | 1 | 150 | 270 | 390 | 453 |
| | Total | 61 | 61 | 62 | 65.5 | 3530 | 4030 | 4790 | 5538 |

Table A 1.8: Agricultural production of Mojo Asha Scheme Yield in a Birr

| S. NO | Crop type | Land in (ha) | | | | Yield in Birr | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2008 | 2009 | 2006 | 2007 | 2008 | 2009 |
| 1 | Tomato | 26 | 27.5 | 27.5 | 28.5 | 1955000 | 2250000 | 2371500 | 3300000 |
| 2 | Pepper | 16 | 15.5 | 15 | 13 | 656640 | 639000 | 743050 | 1330000 |
| 3 | Maize | 6 | 6 | 6.5 | 9 | 212000 | 225000 | 250875 | 440000 |
| 4 | Onion | 7.5 | 8 | 9.5 | 11.5 | 756960 | 888160 | 1092500 | 1200000 |
| 5 | potato | 3.5 | 2.5 | 2 | 2.5 | 269220 | 261450 | 275500 | 147000 |
| 6 | Cabbage | 2 | 1.5 | 1.5 | 1 | 12000 | 11900 | 10450 | 18120 |
| | Total | 61 | 61 | 62 | 65.5 | 3861820 | 4275510 | 4743875 | 6435130 |

**TABLE OF AGRICULTURAL PRODUCTION OF ADANO SCHEME**

Collected from (woreda Agricultural extension expert)

location of the project, PA Mojo Sade

project Name Mojo Asha Scheme

Average Family size_____6_____

Table A 1.9: Agricultural production of Adano Scheme Yield in quintal

| S. NO | Crops type | Land in (ha) | | | | Yield in quintal | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2008 | 2009 | 2006 | 2007 | 2008 | 2009 |
| 1 | Tomato | 14.5 | 15.5 | 17 | 18.5 | 1301 | 1361 | 1651 | 1780 |
| 2 | Pepper | 9.5 | 9 | 11 | 13.5 | 1000 | 950 | 1050 | 1480 |
| 3 | Maize | 23 | 26.5 | 29.5 | 38 | 2030 | 2650 | 2865 | 3990 |
| 4 | Onion | 9 | 10 | 10.5 | 13 | 750 | 800 | 1050 | 1480 |
| 5 | potato | 27.5 | 27.5 | 31.5 | 40 | 3372 | 3310.7 | 4025 | 6560 |
| 6 | Cabbage | 7 | 6.5 | 6.5 | 7 | 1000 | 1100 | 1240 | 1200 |
| | Total | 90.5 | 95 | 106 | 130 | 9453 | 10171.7 | 11881 | 16490 |

Table A 1.10: Agricultural production of Adano Scheme Current price per quintal

| S. NO | Crop type | Land in (ha) | | | | Current price per quintal | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2008 | 2009 | 2006 | 2007 | 2008 | 2009 |
| 1 | Tomato | 14.5 | 15.5 | 17 | 18.5 | 950 | 1000 | 1150 | 1200 |
| 2 | Pepper | 9.5 | 9 | 11 | 13.5 | 780 | 950 | 1200 | 1400 |
| 3 | Maize | 23 | 26.5 | 29.5 | 38 | 400 | 450 | 450 | 550 |
| 4 | Onion | 9 | 10 | 10.5 | 13 | 830 | 910 | 1100 | 1200 |
| 5 | potato | 27.5 | 27.5 | 31.5 | 40 | 420 | 450 | 500 | 735 |
| 6 | Cabbage | 7 | 6.5 | 6.5 | 7 | 150 | 270 | 390 | 453 |
| | Total | 90.5 | 95 | 106 | 130 | 3530 | 4030 | 4790 | 5538 |

Table A 1.11: Agricultural production of Adano Scheme Yield in a Birr

| S. NO | Crops type | Land in (ha) | | | | Yield in Birr | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2008 | 2009 | 2006 | 2007 | 2008 | 2009 |
| 1 | Tomato | 26 | 27.5 | 27.5 | 28.5 | 1235950 | 1361000 | 1898650 | 2136000 |
| 2 | Pepper | 16 | 15.5 | 15 | 13 | 780000 | 902500 | 1260000 | 2072000 |
| 3 | Maize | 6 | 6 | 6.5 | 9 | 812000 | 1192500 | 1289250 | 2194500 |
| 4 | Onion | 7.5 | 8 | 9.5 | 11.5 | 622500 | 728000 | 1155000 | 1776000 |
| 5 | potato | 3.5 | 2.5 | 2 | 2.5 | 1416240 | 1489815 | 2012500 | 4821600 |
| 6 | Cabbage | 2 | 1.5 | 1.5 | 1 | 150000 | 297000 | 483600 | 543600 |
| | Total | 61 | 61 | 62 | 65.5 | 5016690 | 5970815 | 8099000 | 13545000 |

Table A 1.12: Soil test results of Mojo Asha scheme

| Field Location | Depth of soil sample (cm) | Sand (%) | Silt (%) | Clay (%) | Texture class (USDA) | Bulk Density g/cc | Field Capacity (%) | Wilting point (%) | Available Water (mm) |
|---|---|---|---|---|---|---|---|---|---|
| upstream | 0-30 | 33.76 | 32.07 | 34.17 | Clay loam | 1.01 | 29.6 | 18.3 | 113.5 |
| | 30-60 | 33.46 | 32.38 | 34.16 | Clay loam | 1.13 | 29.5 | 18.7 | 108.7 |
| | 60-90 | 33.78 | 30.91 | 35.31 | Clay loam | 1.14 | 28.4 | 16.3 | 126.7 |
| Middle | 0-30 | 33.46 | 32.37 | 34.17 | Clay loam | 1.15 | 31.6 | 21.0 | 155.7 |
| | 30-60 | 33.78 | 32.06 | 34.16 | Clay loam | 1.15 | 31.8 | 18.6 | 122.7 |
| | 60-90 | 31.66 | 32.57 | 35.77 | Clay loam | 1.17 | 32.0 | 19.3 | 126.8 |
| Tail end | 0-30 | 30.46 | 34.37 | 35.17 | Clay loam | 1.27 | 33.6 | 19.9 | 137.4 |
| | 30-60 | 32.78 | 32.06 | 35.16 | Clay loam | 1.15 | 30.8 | 16.7 | 190.7 |
| | 60-90 | 32.77 | 32.57 | 34.66 | Clay loam | 1.35 | 32.7 | 16.7 | 209.3 |

Table A 1.13: Soil test results texture class of Adano scheme

| Field Location | Depth of soil sample (cm) | Sand (%) | Silt (%) | Clay (%) | Texture class (USDA) | Bulk Density g/cc | Field Capacity (%) | Wilting point (%) | Available Water (mm) |
|---|---|---|---|---|---|---|---|---|---|
| upstream | 0-30 | 32.78 | 32.06 | 35.16 | Clay loam | 1.11 | 28.6 | 17.95 | 106.5 |
| | 30-60 | 32.78 | 32.06 | 35.16 | Clay loam | 1.14 | 31.51 | 18.26 | 102.5 |
| | 60-90 | 33.66 | 32.57 | 33.77 | Clay loam | 1.15 | 30.79 | 17.13 | 136.6 |
| Middle | 0-30 | 33.56 | 32.57 | 33.87 | Clay loam | 1.17 | 29.61 | 21.04 | 155.7 |
| | 30-60 | 30.46 | 34.37 | 35.17 | Clay loam | 1.18 | 30.33 | 17.37 | 129.6 |
| | 60-90 | 32.78 | 32.06 | 35.16 | Clay loam | 1.17 | 33.57 | 20.11 | 114.6 |
| Tail end | 0-30 | 33.76 | 32.57 | 33.67 | Clay loam | 1.18 | 32.51 | 19.96 | 145.5 |
| | 30-60 | 32.78 | 32.06 | 35.16 | Clay loam | 1.21 | 35.7 | 16.68 | 220.2 |
| | 60-90 | 33.46 | 32.57 | 33.97 | Clay loam | 1.27 | 32.67 | 17.19 | 214.8 |

Table A 1.14: Soil moisture content of Mojo Asha scheme

| | Before Irrigation | | | | | |
|---|---|---|---|---|---|---|
| Field Location | depth of soil sample (cm) | wet soil Wt (g) | Dry Soil Wt (g) | Moisture content $\theta_w$ (%) | Bulk dencity ($\rho_b$) g/cm$^2$ | Volumetric moisture ($\theta_v$) |
| upstream | 0-30 | 172.21 | 139.6 | 23.4 | 1.07 | 25.0 |
| | 30-60 | 175.4 | 138.8 | 26.4 | 1.13 | 29.8 |
| | 60-90 | 172.71 | 138 | 25.2 | 1.14 | 28.7 |
| Middle | 0-30 | 168.7 | 135.6 | 24.4 | 1.15 | 28.1 |
| | 30-60 | 182.7 | 142.3 | 28.4 | 1.15 | 32.6 |
| | 60-90 | 181.41 | 141.2 | 28.5 | 1.17 | 33.3 |
| Tail end | 0-30 | 172.9 | 138.7 | 24.7 | 1.27 | 31.3 |
| | 30-60 | 170.9 | 136.7 | 25.0 | 1.15 | 28.8 |
| | 60-90 | 173.7 | 135.82 | 27.9 | 1.35 | 37.7 |

| | After Irrigation | | | | | |
|---|---|---|---|---|---|---|
| Field Location | depth of soil sample (cm) | wet soil Wt (g) | Dry Soil Wt (g) | Moisture content $\theta_w$ (%) | Bulk dencity ($\rho_b$) g/cm$^2$ | Volumetric moisture ($\theta_v$) |
| upstream | 0-30 | 174.7 | 133.8 | 30.6 | 1.01 | 30.9 |
| | 30-60 | 182.7 | 138.2 | 32.2 | 1.11 | 35.7 |
| | 60-90 | 173.9 | 135.3 | 28.5 | 1.12 | 32.0 |
| Middle | 0-30 | 172.9 | 130.21 | 32.8 | 1.13 | 37.0 |
| | 30-60 | 185.8 | 138.8 | 33.9 | 1.14 | 38.6 |
| | 60-90 | 186 | 140 | 32.9 | 1.15 | 37.8 |
| Tail end | 0-30 | 184.7 | 137.8 | 34.0 | 1.17 | 39.8 |
| | 30-60 | 182.45 | 138.95 | 31.3 | 1.14 | 35.7 |
| | 60-90 | 184.9 | 138.8 | 33.2 | 1.19 | 39.5 |

Table A 1.15: Soil moisture content of Adano scheme

| | Before Irrigation | | | | | |
|---|---|---|---|---|---|---|
| Field Location | depth of soil sample (cm) | wet soil Wt (g) | Dry Soil Wt (g) | Moisture content $\theta_w$ (%) | Bulk dencity ($\rho_b$) g/cm$^2$ | Volumetric moisture ($\theta_v$) |
| upstream | 0-30 | 168.5 | 136.8 | 23.2 | 1.13 | 27.3 |
| | 30-60 | 171.9 | 135.7 | 26.7 | 1.14 | 30.9 |
| | 60-90 | 174.11 | 137.8 | 26.3 | 1.15 | 31.9 |
| Middle | 0-30 | 167.9 | 135.4 | 24.0 | 1.17 | 28.1 |
| | 30-60 | 171.9 | 138.5 | 24.1 | 1.18 | 28.5 |
| | 60-90 | 179.4 | 139.7 | 28.4 | 1.17 | 33.2 |
| Tail end | 0-30 | 169.9 | 134.1 | 26.7 | 1.18 | 32.3 |
| | 30-60 | 172.7 | 132.9 | 29.9 | 1.21 | 34.1 |
| | 60-90 | 169.8 | 134.05 | 26.7 | 1.27 | 30.1 |

| | After Irrigation | | | | | |
|---|---|---|---|---|---|---|
| Field Location | depth of soil sample (cm) | wet soil Wt (g) | Dry Soil Wt (g) | Moisture content $\theta_w$ (%) | Bulk dencity ($\rho_b$) g/cm$^2$ | Volumetric moisture ($\theta_v$) |
| upstream | 0-30 | 171.9 | 131 | 31.2 | 1.01 | 35.6 |
| | 30-60 | 178.9 | 136.4 | 31.2 | 1.13 | 35.8 |
| | 60-90 | 173.5 | 132.5 | 30.9 | 1.13 | 36.8 |
| Middle | 0-30 | 169.9 | 130.41 | 30.3 | 1.15 | 34.8 |
| | 30-60 | 175.9 | 133.9 | 31.4 | 1.15 | 36.1 |
| | 60-90 | 184 | 137.2 | 34.1 | 1.13 | 38.5 |
| Tail end | 0-30 | 178.9 | 133 | 34.5 | 1.16 | 41.8 |
| | 30-60 | 177.4 | 130.15 | 36.3 | 1.19 | 40.7 |
| | 60-90 | 174.9 | 131.7 | 32.8 | 1.17 | 33.5 |

Table A 1.16: Soil moisture depletion and actual soil moisture stored in the root zone (mm)

| Selected Field | Depth of soil sample (cm) | Mojo Asha Scheme | | Adano Scheme | |
|---|---|---|---|---|---|
| | | SMD (mm) | AMS (mm) | SMD (mm) | AMS (mm) |
| Field I | 0-30 | 18.75 | 21.53 | 16.28 | 25.62 |
| | 30-60 | 9.45 | 18.69 | 14.50 | 15.25 |
| | 60-90 | 9.71 | 10.73 | 13.32 | 13.78 |
| Field II | 0-30 | 21.60 | 25.13 | 16.82 | 18.84 |
| | 30-60 | 10.32 | 16.41 | 18.64 | 21.75 |
| | 60-90 | 10.54 | 13.14 | 15.46 | 17.08 |
| Field III | 0-30 | 26.83 | 28.13 | 17.44 | 23.44 |
| | 30-60 | 17.35 | 18.86 | 17.26 | 19.07 |
| | 60-90 | 14.00 | 15.69 | 18.00 | 18.40 |

AMS is actual moisture storage and SMD is soil moisture depletion

Table A 1.17: First and second seasons crop water requirement of Mojo Asha irrigation scheme

| Mojo Asha scheme | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Types of Crop | Area (ha) | First Season (Sep - Dec) | | | | Second Season (Jan - April) | | | | |
| | | CWR (mm/ season) | IWR (mm/ season) | TRF (mm/ season) | Eff RF (mm/ season) | Area (ha) | CWR (mm/ season) | IWR (mm/ season) | TRF (mm/ season) | Eff RF (mm/ season) |
| Tomato | 28.5 | 531.3 | 393.3 | 147.0 | 141.0 | 5 | 607.1 | 295.7 | 380.4 | 306.5 |
| pepper | 13 | 431.9 | 273.6 | 180.1 | 162.3 | 10 | 485.5 | 241.5 | 299.1 | 243.8 |
| Onion | 11.5 | 350.4 | 196.0 | 172.5 | 154.7 | 9 | 382.2 | 249.1 | 148.1 | 130.6 |
| Potato | 2.5 | 467.1 | 313.6 | 182.6 | 164.4 | 2 | 529.2 | 269.2 | 323.2 | 261.4 |
| Maize | 9 | 410.5 | 277.9 | 180.1 | 162.3 | 23 | 466.2 | 246.0 | 299.1 | 243.8 |
| Cabbage | 1 | 591.5 | 409.0 | 201.0 | 184.7 | 2 | 683.0 | 314.5 | 446.2 | 363.8 |
| Total | 65.5 | | | | | 51 | | | | |

Table A 1.18: First and second seasons crop water requirement of Adano irrigation scheme

| Adano Scheme | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Types of Crop | Area (ha) | First Season (Sep - Dec) | | | | Second Season (Jan - April) | | | | |
| | | CWR (mm/ season) | IWR (mm/ season) | TRF (mm/ season) | Eff RF (mm/ season) | Area (ha) | CWR (mm/ season) | IWR (mm/ season) | TRF (mm/ season) | Eff RF (mm/ season) |
| Tomato | 18.5 | 531.3 | 393.3 | 147.0 | 141.0 | 10 | 607.1 | 295.7 | 380.4 | 306.5 |
| pepper | 13.5 | 431.9 | 273.6 | 180.5 | 162.3 | 12 | 485.5 | 241.5 | 299.1 | 243.8 |
| Onion | 13 | 350.4 | 196.0 | 172.5 | 154.7 | 13 | 382.2 | 249.1 | 148.1 | 130.6 |
| Potato | 40 | 467.1 | 313.6 | 182.6 | 164.4 | 17 | 529.2 | 269.2 | 323.2 | 261.4 |
| Maize | 38 | 410.5 | 277.9 | 180.5 | 162.3 | 55 | 466.2 | 246.0 | 299.1 | 243.8 |
| Cabbage | 7 | 591.5 | 409.0 | 201.0 | 184.7 | 3 | 683.0 | 314.5 | 446.2 | 363.8 |
| Total | 130 | | | | | 110 | | | | |

Table A 1.19: First Season Crop water requirement of Tomato

ETo station: GIRAWA Crop: Tomato

Rain station: GIRAWA Planting date: 02/09

| Month | Decade | Stage | Kc coeff | ETc mm/da | ETc mm/de | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Sep | 2 | Init | 0.60 | 2.52 | 25.2 | 30.1 | 0.0 |
| Sep | 2 | Init | 0.60 | 2.48 | 24.8 | 23.2 | 1.5 |
| Sep | 3 | Init | 0.60 | 2.46 | 24.6 | 20.2 | 4.4 |
| Oct | 1 | Deve | 0.67 | 2.76 | 27.6 | 16.9 | 10.7 |
| Oct | 2 | Deve | 0.81 | 3.29 | 32.9 | 13.1 | 19.9 |
| Oct | 3 | Deve | 0.95 | 3.86 | 42.4 | 12.8 | 29.7 |
| Nov | 1 | Mid | 1.09 | 4.41 | 44.1 | 13.6 | 30.6 |
| Nov | 2 | Mid | 1.14 | 4.60 | 46.0 | 13.2 | 32.7 |
| Nov | 3 | Mid | 1.14 | 4.53 | 45.3 | 9.7 | 35.5 |
| Dec | 1 | Mid | 1.14 | 4.46 | 44.6 | 4.8 | 39.8 |
| Dec | 2 | Mid | 1.14 | 4.39 | 43.9 | 1.0 | 42.8 |
| Dec | 3 | Late | 1.11 | 4.32 | 47.5 | 2.4 | 45.1 |
| Jan | 1 | Late | 0.99 | 3.91 | 39.1 | 4.2 | 34.8 |
| Jan | 2 | Late | 0.88 | 3.48 | 34.8 | 5.0 | 29.8 |
| Jan | 3 | Late | 0.80 | 3.24 | 9.7 | 1.7 | 6.7 |
| Total | | | | | 532.4 | 171.9 | 364.0 |

Table A 1.20: Second Season Crop water requirement of Tomato

ETo station: GIRAWA Crop: Tomato

Rain station: GIRAWA Planting date: 15/01

| Month | Decade | Stage | Kc coeff | ETc mm/da | ETc mm/de | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Jan | 2 | Init | 0.60 | 2.38 | 14.3 | 3.0 | 11.8 |
| Jan | 3 | Init | 0.60 | 2.43 | 26.7 | 6.1 | 20.7 |
| Feb | 1 | Init | 0.60 | 2.48 | 24.8 | 6.8 | 18.0 |
| Feb | 2 | Deve | 0.64 | 2.69 | 26.9 | 7.7 | 19.2 |
| Feb | 3 | Deve | 0.76 | 3.28 | 26.2 | 10.1 | 16.2 |
| Mar | 1 | Deve | 0.88 | 3.91 | 39.1 | 11.8 | 27.4 |
| Mar | 2 | Deve | 1.02 | 4.64 | 46.4 | 13.6 | 32.8 |
| Mar | 3 | Mid | 1.14 | 5.19 | 57.1 | 19.0 | 38.2 |
| Apr | 1 | Mid | 1.15 | 5.27 | 52.7 | 25.2 | 27.5 |
| Apr | 2 | Mid | 1.15 | 5.29 | 52.9 | 30.4 | 22.5 |
| Apr | 3 | Mid | 1.15 | 5.32 | 53.2 | 33.3 | 19.9 |
| May | 1 | Late | 1.15 | 5.34 | 53.4 | 38.4 | 15.1 |
| May | 2 | Late | 1.07 | 5.03 | 50.3 | 42.7 | 7.5 |
| May | 3 | Late | 0.95 | 4.55 | 50.1 | 36.6 | 13.5 |
| Jun | 1 | Late | 0.84 | 4.11 | 32.9 | 21.8 | 5.6 |
| Total | | | | | 607.1 | 306.5 | 295.7 |

Table A 1.21: First Season Crop water requirement of Peppers

ETo station: GIRAWA Crop: Peppers

Rain station: GIRAWA Planting date: 03/09

| Month | Decade | Stage | Kc coeff | ETc mm/da | ETc mm/de | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Sep | 1 | Init | 0.60 | 2.52 | 25.2 | 30.1 | 0.0 |
| Sep | 2 | Init | 0.60 | 2.48 | 24.8 | 23.2 | 1.5 |
| Sep | 3 | Init | 0.60 | 2.46 | 24.6 | 20.2 | 4.4 |
| Oct | 1 | Deve | 0.67 | 2.73 | 27.3 | 16.9 | 10.5 |
| Oct | 2 | Deve | 0.80 | 3.23 | 32.3 | 13.1 | 19.3 |
| Oct | 3 | Deve | 0.93 | 3.76 | 41.3 | 12.8 | 28.6 |
| Nov | 1 | Mid | 1.03 | 4.18 | 41.8 | 13.6 | 28.2 |
| Nov | 2 | Mid | 1.04 | 4.19 | 41.9 | 13.2 | 28.7 |
| Nov | 3 | Mid | 1.04 | 4.13 | 41.3 | 9.7 | 31.6 |
| Dec | 1 | Mid | 1.04 | 4.06 | 40.6 | 4.8 | 35.9 |
| Dec | 2 | Late | 1.02 | 3.94 | 39.4 | 1.0 | 38.3 |
| Dec | 3 | Late | 0.95 | 3.69 | 40.6 | 2.4 | 38.2 |
| Jan | 1 | Late | 0.90 | 3.52 | 10.6 | 1.3 | 8.4 |
| Total | | | | | 431.9 | 162.3 | 273.6 |

Table A 1.22: Second Season Crop water requirement of Onion

ETo station: GIRAWA Crop: Onion

Rain station: GIRAWA Planting date: 17/01

| Month | Decade | Stage | Kc coeff | ETc mm/day | ETc mm/dec | Eff rain mm/dec | Irr. Req. mm/de |
|---|---|---|---|---|---|---|---|
| Jan | 2 | Init | 0.70 | 2.78 | 16.7 | 3.0 | 14.2 |
| Jan | 3 | Init | 0.70 | 2.84 | 31.2 | 6.1 | 25.1 |
| Feb | 1 | Deve | 0.73 | 3.03 | 30.3 | 6.8 | 23.4 |
| Feb | 2 | Deve | 0.85 | 3.57 | 35.7 | 7.7 | 28.0 |
| Feb | 3 | Deve | 0.95 | 4.13 | 33.0 | 10.1 | 22.9 |
| Mar | 1 | Mid | 1.04 | 4.63 | 46.3 | 11.8 | 34.5 |
| Mar | 2 | Mid | 1.05 | 4.80 | 48.0 | 13.6 | 34.4 |
| Mar | 3 | Mid | 1.05 | 4.82 | 53.0 | 19.0 | 34.0 |
| Apr | 1 | Late | 1.04 | 4.77 | 47.7 | 25.2 | 22.5 |
| Apr | 2 | Late | 0.98 | 4.49 | 40.4 | 27.3 | 10.1 |
| Total | | | | | 382.2 | 130.6 | 249.1 |

Table A 1.23: First Season Crop water requirement of Onion

ETo station: GIRAWA Crop: Onion

Rain station: GIRAWA Planting date: 05/09

| Month | Decade | Stage | Kc coeff | ETc mm/da | ETc mm/d | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Sep | 1 | Init | 0.70 | 2.94 | 29.4 | 30.1 | 0.0 |
| Sep | 2 | Init | 0.70 | 2.89 | 28.9 | 23.2 | 5.7 |
| Sep | 3 | Deve | 0.76 | 3.13 | 31.3 | 20.2 | 11.1 |
| Oct | 1 | Deve | 0.88 | 3.58 | 35.8 | 16.9 | 18.9 |
| Oct | 2 | Deve | 0.99 | 4.02 | 40.2 | 13.1 | 27.2 |
| Oct | 3 | Mid | 1.04 | 4.22 | 46.4 | 12.8 | 33.6 |
| Nov | 1 | Mid | 1.04 | 4.20 | 42.0 | 13.6 | 28.5 |
| Nov | 2 | Late | 1.04 | 4.19 | 41.9 | 13.2 | 28.7 |
| Nov | 3 | Late | 1.00 | 3.96 | 39.6 | 9.7 | 29.9 |
| Dec | 1 | Late | 0.95 | 3.72 | 14.9 | 1.9 | 12.5 |
| Total | | | | | 350.4 | 154.7 | 196.0 |

Table A 1.24: Second Season Crop water requirement of Onion

ETo station: GIRAWA Crop: Onion

Rain station: GIRAWA Planting date: 19/01

| Month | Decade | Stage | Kc coeff | ETc mm/day | ETc mm/dec | Eff rain mm/dec | Irr. Req. mm/de |
|---|---|---|---|---|---|---|---|
| Jan | 2 | Init | 0.70 | 2.78 | 16.7 | 3.0 | 14.2 |
| Jan | 3 | Init | 0.70 | 2.84 | 31.2 | 6.1 | 25.1 |
| Feb | 1 | Deve | 0.73 | 3.03 | 30.3 | 6.8 | 23.4 |
| Feb | 2 | Deve | 0.85 | 3.57 | 35.7 | 7.7 | 28.0 |
| Feb | 3 | Deve | 0.95 | 4.13 | 33.0 | 10.1 | 22.9 |
| Mar | 1 | Mid | 1.04 | 4.63 | 46.3 | 11.8 | 34.5 |
| Mar | 2 | Mid | 1.05 | 4.80 | 48.0 | 13.6 | 34.4 |
| Mar | 3 | Mid | 1.05 | 4.82 | 53.0 | 19.0 | 34.0 |
| Apr | 1 | Late | 1.04 | 4.77 | 47.7 | 25.2 | 22.5 |
| Apr | 2 | Late | 0.98 | 4.49 | 40.4 | 27.3 | 10.1 |
| Total | | | | | 382.2 | 130.6 | 249.1 |

Table A 1.25: First Season Crop water requirement of Potato

ETo station: GIRAWA Crop: Potato

Rain station: GIRAWA Planting date: 01/09

| Month | Decade | Stage | Kc coeff | ETc mm/da | ETc mm/d | Eff rain mm/dec | Irr.Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Sep | 1 | Init | 0.50 | 2.10 | 21.0 | 30.1 | 0.0 |
| Sep | 2 | Init | 0.50 | 2.06 | 20.6 | 23.2 | 0.0 |
| Sep | 3 | Deve | 0.53 | 2.18 | 21.8 | 20.2 | 1.6 |
| Oct | 1 | Deve | 0.72 | 2.96 | 29.6 | 16.9 | 12.7 |
| Oct | 2 | Deve | 0.94 | 3.81 | 38.1 | 13.1 | 25.0 |
| Oct | 3 | Mid | 1.12 | 4.54 | 50.0 | 12.8 | 37.2 |
| Nov | 1 | Mid | 1.14 | 4.61 | 46.1 | 13.6 | 32.5 |
| Nov | 2 | Mid | 1.14 | 4.59 | 45.9 | 13.2 | 32.7 |
| Nov | 3 | Mid | 1.14 | 4.52 | 45.2 | 9.7 | 35.5 |
| Dec | 1 | Late | 1.14 | 4.45 | 44.5 | 4.8 | 39.7 |
| Dec | 2 | Late | 1.05 | 4.05 | 40.5 | 1.0 | 39.4 |
| Dec | 3 | Late | 0.91 | 3.55 | 39.0 | 2.4 | 36.6 |
| Jan | 1 | Late | 0.79 | 3.09 | 24.7 | 3.4 | 20.5 |
| Total | | | | | 467.1 | 164.4 | 313.6 |

Table A 1.26: Second Season Crop water requirement of Potato

ETo station: GIRAWA Crop: Potato

Rain station: GIRAWA Planting date: 15/01

| Month | Decade | Stage | Kc coeff | ETc mm/day | ETc mm/dec | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Jan | 2 | Init | 0.50 | 1.99 | 11.9 | 3.0 | 9.4 |
| Jan | 3 | Init | 0.50 | 2.03 | 22.3 | 6.1 | 16.2 |
| Feb | 1 | Deve | 0.51 | 2.09 | 20.9 | 6.8 | 14.1 |
| Feb | 2 | Deve | 0.66 | 2.79 | 27.9 | 7.7 | 20.2 |
| Feb | 3 | Deve | 0.86 | 3.71 | 29.7 | 10.1 | 19.6 |
| Mar | 1 | Deve | 1.05 | 4.68 | 46.8 | 11.8 | 35.0 |
| Mar | 2 | Mid | 1.15 | 5.24 | 52.4 | 13.6 | 38.8 |
| Mar | 3 | Mid | 1.15 | 5.26 | 57.9 | 19.0 | 38.9 |
| Apr | 1 | Mid | 1.15 | 5.28 | 52.8 | 25.2 | 27.6 |
| Apr | 2 | Mid | 1.15 | 5.30 | 53.0 | 30.4 | 22.6 |
| Apr | 3 | Late | 1.12 | 5.20 | 52.0 | 33.3 | 18.6 |
| May | 1 | Late | 1.00 | 4.64 | 46.4 | 38.4 | 8.0 |
| May | 2 | Late | 0.86 | 4.04 | 40.4 | 42.7 | 0.0 |
| May | 3 | Late | 0.77 | 3.68 | 14.7 | 13.3 | 0.0 |
| Total | | | | | 529.2 | 261.4 | 269.2 |

Table A 1.27: First Season Crop water requirement of Maize

ETo Station: GIRAWA Crop: MAIZE (Grain)

Rain Station: GIRAWA Planting date: 01/09

| Month | Decade | Stage | Kc coeff | ETc mm/da | ETc mm/d | Eff rain mm/de | Irr. Req. mm/de |
|---|---|---|---|---|---|---|---|
| Sep | 1 | Init | 0.30 | 1.26 | 12.6 | 30.1 | 0.0 |
| Sep | 2 | Init | 0.30 | 1.24 | 12.4 | 23.2 | 0.0 |
| Sep | 3 | Deve | 0.44 | 1.80 | 18.0 | 20.2 | 0.0 |
| Oct | 1 | Deve | 0.69 | 2.83 | 28.3 | 16.9 | 11.4 |
| Oct | 2 | Deve | 0.94 | 3.84 | 38.4 | 13.1 | 25.4 |
| Oct | 3 | Mid | 1.16 | 4.71 | 51.8 | 12.8 | 39.1 |
| Nov | 1 | Mid | 1.19 | 4.79 | 47.9 | 13.6 | 34.3 |
| Nov | 2 | Mid | 1.19 | 4.78 | 47.8 | 13.2 | 34.5 |
| Nov | 3 | Mid | 1.19 | 4.70 | 47.0 | 9.7 | 37.3 |
| Dec | 1 | Late | 1.13 | 4.40 | 44.0 | 4.8 | 39.3 |
| Dec | 2 | Late | 0.86 | 3.33 | 33.3 | 1.0 | 32.2 |
| Dec | 3 | Late | 0.57 | 2.23 | 24.5 | 2.4 | 22.1 |
| Jan | 1 | Late | 0.38 | 1.48 | 4.5 | 1.3 | 2.3 |
| Total | | | | | 410.5 | 162.3 | 277.9 |

Table A 1.28: Second Season Crop water requirement of Maize

ETo Station: GIRAWA Crop: MAIZE (Grain)

Rain Station: GIRAWA Planting date: 15/01

| Month | Decade | Stage | Kc coeff | ETc mm/day | ETc mm/dec | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Jan | 2 | Init | 0.30 | 1.19 | 7.1 | 3.0 | 4.6 |
| Jan | 3 | Init | 0.30 | 1.22 | 13.4 | 6.1 | 7.3 |
| Feb | 1 | Deve | 0.37 | 1.54 | 15.4 | 6.8 | 8.5 |
| Feb | 2 | Deve | 0.62 | 2.62 | 26.2 | 7.7 | 18.5 |
| Feb | 3 | Deve | 0.85 | 3.69 | 29.6 | 10.1 | 19.5 |
| Mar | 1 | Deve | 1.09 | 4.82 | 48.2 | 11.8 | 36.4 |
| Mar | 2 | Mid | 1.20 | 5.47 | 54.7 | 13.6 | 41.1 |
| Mar | 3 | Mid | 1.20 | 5.49 | 60.4 | 19.0 | 41.5 |
| Apr | 1 | Mid | 1.20 | 5.51 | 55.1 | 25.2 | 30.0 |
| Apr | 2 | Late | 1.20 | 5.52 | 55.2 | 30.4 | 24.8 |
| Apr | 3 | Late | 1.02 | 4.71 | 47.1 | 33.3 | 13.8 |
| May | 1 | Late | 0.73 | 3.41 | 34.1 | 38.4 | 0.0 |
| May | 2 | Late | 0.46 | 2.17 | 19.5 | 38.5 | 0.0 |
| Total | | | | | 466.2 | 243.8 | 246.0 |

Table A 1.29: First Season Crop water requirement of Cabbage

ETo station: GIRAWA Crop: CABBAGE

Rain station: GIRAWA Planting date: 01/09

| Month | Decade | Stage | Kc coeff | ETc mm/day | ETc mm/dec | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Sep | 1 | Init | 0.70 | 2.94 | 29.4 | 30.1 | 0.0 |
| Sep | 2 | Init | 0.70 | 2.89 | 28.9 | 23.2 | 5.7 |
| Sep | 3 | Init | 0.70 | 2.87 | 28.7 | 20.2 | 8.5 |
| Oct | 1 | Init | 0.70 | 2.86 | 28.6 | 16.9 | 11.7 |
| Oct | 2 | Deve | 0.73 | 2.97 | 29.7 | 13.1 | 16.7 |
| Oct | 3 | Deve | 0.79 | 3.21 | 35.3 | 12.8 | 22.5 |
| Nov | 1 | Deve | 0.85 | 3.44 | 34.4 | 13.6 | 20.8 |
| Nov | 2 | Deve | 0.91 | 3.66 | 36.6 | 13.2 | 23.3 |
| Nov | 3 | Deve | 0.96 | 3.83 | 38.3 | 9.7 | 28.5 |
| Dec | 1 | Mid | 1.02 | 3.99 | 39.9 | 4.8 | 35.1 |
| Dec | 2 | Mid | 1.04 | 4.00 | 40.0 | 1.0 | 39.0 |
| Dec | 3 | Mid | 1.04 | 4.04 | 44.5 | 2.4 | 42.1 |
| Jan | 1 | Mid | 1.04 | 4.09 | 40.9 | 4.2 | 36.6 |
| Jan | 2 | Mid | 1.04 | 4.13 | 41.3 | 5.0 | 36.3 |
| Jan | 3 | Late | 1.04 | 4.20 | 46.2 | 6.1 | 40.1 |
| Feb | 1 | Late | 0.99 | 4.08 | 40.8 | 6.8 | 34.0 |
| Feb | 2 | Late | 0.95 | 4.01 | 8.0 | 1.5 | 8.0 |
| Total | | | | | 591.5 | 184.7 | 409.0 |

Table A 1.30: Second Season Crop water requirement of Cabbage

ETo station: GIRAWA Crop: CABBAGE

Rain station: GIRAWA Planting date: 20/01

| Month | Decade | Stage | Kc coeff | ETc mm/da | ETc mm/de | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Jan | 2 | Init | 0.70 | 2.78 | 2.8 | 0.5 | 2.8 |
| Jan | 3 | Init | 0.70 | 2.84 | 31.2 | 6.1 | 25.1 |
| Feb | 1 | Init | 0.70 | 2.89 | 28.9 | 6.8 | 22.1 |
| Feb | 2 | Init | 0.70 | 2.95 | 29.5 | 7.7 | 21.8 |
| Feb | 3 | Init | 0.70 | 3.03 | 24.2 | 10.1 | 14.2 |
| Mar | 1 | Deve | 0.73 | 3.25 | 32.5 | 11.8 | 20.8 |
| Mar | 2 | Deve | 0.79 | 3.61 | 36.1 | 13.6 | 22.5 |
| Mar | 3 | Deve | 0.85 | 3.90 | 42.9 | 19.0 | 24.0 |
| Apr | 1 | Deve | 0.92 | 4.20 | 42.0 | 25.2 | 16.8 |
| Apr | 2 | Deve | 0.97 | 4.49 | 44.9 | 30.4 | 14.5 |
| Apr | 3 | Mid | 1.03 | 4.78 | 47.8 | 33.3 | 14.5 |
| May | 1 | Mid | 1.05 | 4.91 | 49.1 | 38.4 | 10.7 |
| May | 2 | Mid | 1.05 | 4.93 | 49.3 | 42.7 | 6.6 |
| May | 3 | Mid | 1.05 | 5.04 | 55.4 | 36.6 | 18.8 |
| Jun | 1 | Mid | 1.05 | 5.14 | 51.4 | 27.3 | 24.1 |
| Jun | 2 | Late | 1.05 | 5.23 | 52.3 | 21.3 | 31.0 |
| Jun | 3 | Late | 1.01 | 4.89 | 48.9 | 24.6 | 24.3 |
| Jul | 1 | Late | 0.96 | 4.59 | 13.8 | 8.5 | 0.0 |
| Total | | | | | 683.0 | 363.8 | 314.5 |

Table A 1.31: First and second season irrigation schedules and Crop type of study area.

| Cabbage | | Potato | | Pepper | |
|---|---|---|---|---|---|
| Date | day | Date | day | Date | day |
| First season | | First season | | First season | |
| Sep | 1 | 20-Sep | 1 | 1-Sep | 1 |
| 22-Sep | 22 | 1-Oct | 11 | 5-Sep | 5 |
| 12-Oct | 42 | 10-Oct | 40 | 10-Sep | 10 |
| 2-Oct | 56 | 21-Oct | 51 | 21-Sep | 21 |
| 9-Nov | 70 | 30-Oct | 60 | 6-Oct | 36 |
| 22-Nov | 83 | 9-Nov | 70 | 20-Oct | 50 |
| 3-Dec | 94 | 19-Nov | 80 | 5-Nov | 66 |
| 13-Dec | 104 | 28-Nov | 89 | 19-Nov | 80 |
| 23-Dec | 114 | 5-Dec | 96 | 1-Dec | 92 |
| 2-Jan | 124 | 13-Dec | 104 | 12-Dec | 103 |
| 12-Jan | 134 | 24-Dec | 115 | 28-Dec | 119 |
| 22-Jan | 144 | 8-Jan | End | 3-Jan | End |
| 1-Feb | 154 | Second season | | Second season | |
| 12-Feb | End | 15-Jan | 1 | 15-Jan | 1 |
| Second season | | 21-Jan | 7 | 20-Jan | 6 |
| 20-Jan | 1 | 29-Jan | 15 | 25-Jan | 11 |
| 29-Jan | 10 | 6-Feb | 23 | 31-Jan | 17 |
| 6-Feb | 18 | 14-Feb | 31 | 8-Feb | 25 |
| 15-Feb | 27 | 22-Feb | 39 | 16-Feb | 33 |
| 26-Feb | 38 | 2-Mar | 47 | 25-Feb | 42 |
| 10-Mar | 50 | 10-Mar | 55 | 10-Mar | 55 |
| 22-Mar | 62 | 19-Mar | 64 | 22-Mar | 67 |
| 2-Apr | 73 | 29-Mar | 74 | 6-Apr | 82 |
| 22-Apr | 93 | 10-Apr | 86 | 19-Apr | End |
| 2-Jun | 134 | 21-Apr | 97 | | |
| 15-Jun | 147 | 24-May | End | | |
| 26-Jun | 158 | | | | |
| 3-Jul | End | | | | |

| Tomato | | Onion | | Maize | |
|---|---|---|---|---|---|
| Date | day | Date | day | Date | day |
| First season | | First season | | First season | |
| 15-Sep | 1 | 1-Sep | 1 | 15-Oct | 1 |
| 20-Sep | 6 | 6-Sep | 6 | 7-Nov | 24 |
| 1-Oct | 17 | 12-Sep | 12 | 27-Nov | 44 |
| 12-Oct | 28 | 2-Oct | 32 | 17-Dec | 63 |
| 26-Oct | 42 | 20-Oct | 50 | 15-Jan | 95 |
| 11-Nov | 58 | 5-Nov | 66 | 21-Feb | End |
| 30-Nov | 77 | 20-Nov | 81 | Second season | |
| 16-Dec | 93 | 4-Dec | End | 15-Jan | 1 |
| 31 Dec | 108 | Second season | | 6-Feb | 23 |
| 19 Jan | 127 | 15-Jan | 1 | 28-Feb | 45 |
| 6-Feb | End | 20-Jan | 6 | 20-Mar | 65 |
| Second season | | 25-Jan | 11 | 22-Apr | 98 |
| 1-Jan | 1 | 31-Jan | 17 | 19-May | End |
| 15 | | 8-Feb | 25 | | |
| 20-Jan | 6 | 16-Feb | 33 | | |
| 26-Jan | 12 | 25-Feb | 42 | | |
| 1-Feb | 18 | 10-Mar | 55 | | |
| 10-Feb | 27 | 22-Mar | 67 | | |
| 21-Feb | 38 | 6-Apr | 82 | | |
| 6-Mar | 51 | 19-Apr | End | | |
| 20-Mar | 65 | | | | |
| 11-Apr | 87 | | | | |
| 8-Jun | End | | | | |

**Annex Figures**

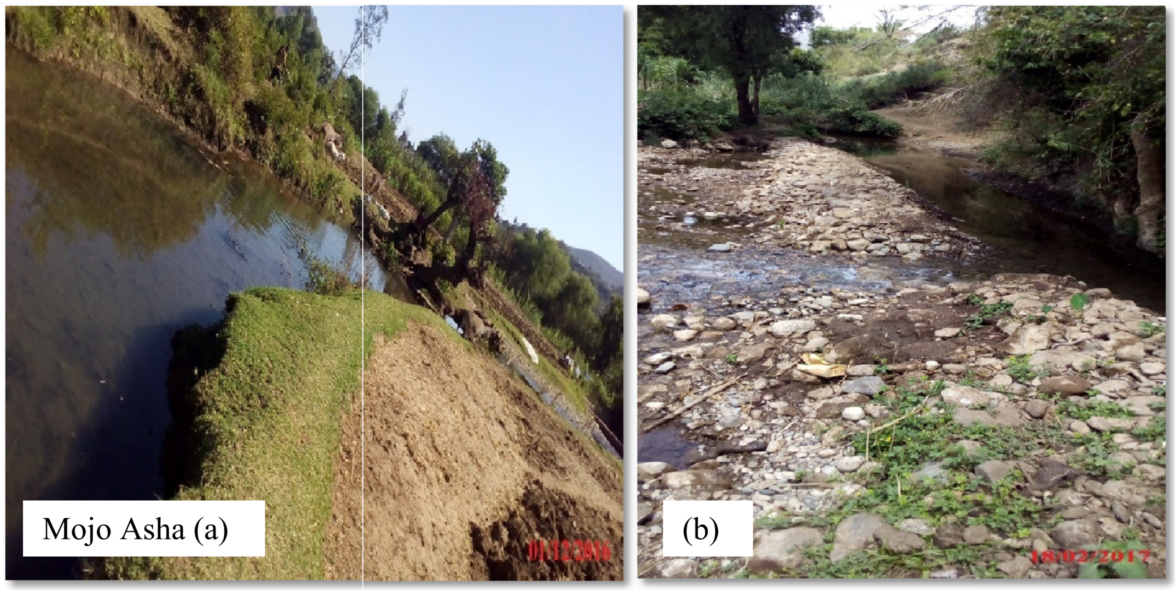


Figure A 1.1: Poor water managements of main canals at Mojo Asha irrigation scheme.


Figure A 1.2:  Poor water managements of main canals at Adano irrigation scheme.


Figure A 1.3: Poor managements of secondary canals at Mojo Asha irrigation scheme.


Figure A 1.4: Poor water managements of secondary canals at Adano irrigation scheme.


Figure A 1.5: Farmers interview in their farm at Mojo Asha irrigation scheme.


Figure A 1.6: Farmers interview in their farm at Adano irrigation scheme.

**Annex B. The questionnaire survey to establish the production data of Mojo Asha and Adano small scale irrigation schemes**

Zone...................Woreda...................PA______________ Project name....................

Farmer name..................................          Enumerator name..........................................

**Yield for 2016/2017 cropped year**

What are the major crops?   1.________2. _________3.__________4._________

Land holding ______________Ha

Depending on types of crop to fill the following tables

For first season / I session

| No | Type of crop | Land (ha) | Irrigation interval | Production yield in quintal | Current cost of production |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |

For second season/ II session

| No | Type of crop | Land (ha) | Irrigation interval | Production yield in quintal | Current cost of production |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |