



**PERFORMANCE EVALUATION OF IRRIGATION SCHEMES:
A CASE STUDY OF JARI AND ALOMA SMALL-SCALE
IRRIGATION SCHEMES,
TEHULEDERE DISTRICT, ETHIOPIA**

M.Sc THESIS

SOLOMON WONDATIR TAYE

FEBRUARY, 2016

ARBA MINCH, ETHIOPIA

**PERFORMANCE EVALUATION OF IRRIGATION SCHEMES:
A CASE STUDY OF JARI AND ALOMA SMALL-SCALE
IRRIGATION SCHEMES,
TEHULEDERE DISTRICT, ETHIOPIA**

SOLOMON WONDATIR TAYE

A THESIS SUBMITTED TO THE DEPARTMENT OF
WATER RESOURCE AND IRRIGATION ENGINEERING,
INSTITUTE OF TECHNOLOGY, SCHOOL OF GRADUATE STUDIES
ARBA MINCH UNIVESITY

IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE IN
IRRIGATION AND DRAINAGE ENGINEERING

FEBRUARY, 2016

ARBA MINCH

DECLARATIONS

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

Name: _____

Signature: _____

Date: _____

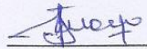
APPROVAL PAGE

This thesis entitled with “*Performance Evaluation of Irrigation Schemes: A Case Study of Jari and Aloma Small-Scale Irrigation Schemes, Tehuledere District, Ethiopia*” has been approved by the research advisors, examiners, SGS coordination and department head for the partial fulfillment of the requirements for the degree of Master of Science in Water Resources and Irrigation Engineering.

Date of Defense: February 27, 2016

Submitted by;

Mr. Solomon Wondatir
(Name)


Signature

24-03-16
Date


Approved by;

1. Alemseged Tamiru (PhD)
(External Examiner)


Signature

23-03-16
Date

2. Santosh M. Pingale (PhD)
(Internal Examiner)


Signature


25/03/2016
Date

3. Mr. Alemayehu Kasaye
(Chairman)


Signature


Date

4. Zelege Agide (PhD)
(Principal Advisor)


Signature

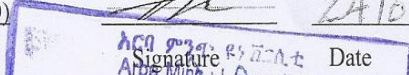
23/03/16
Date

5. Yigzaw Dessalegn (PhD)
(Co-Advisor)


Signature

24/03/16
Date

6. Mr. Alemayehu Kasaye
(Department Head)


Signature

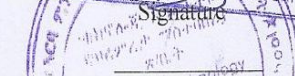
Date

7. Mr. Demelash Wendimagegnehu
(PG coordinator)

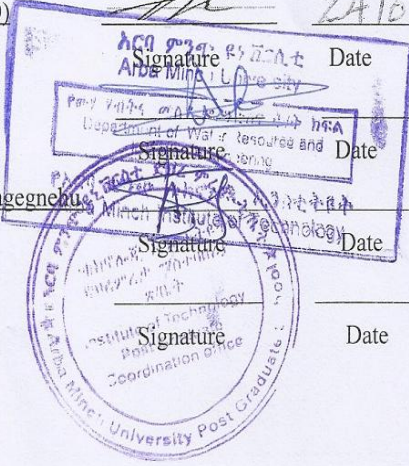

Signature

Date

8. Anto Arkato (PhD)
(Postgraduate Director)


Signature

Date



DEDICATION

This thesis manuscript is dedicated to my **MOTHER, BAYUSH YIMER**, for her love and sacrifice in the success of my life.

BIOGRAPHICAL SKETCH

The author was born in January 16, 1984 in Woldia town. He attended his elementary education in Melka-Kole elementary school, and senior elementary school at Melesitegna senior elementary school, in Woldia. He followed his secondary education in Woldia high school.

In 2003 he completed his high school education and joined Haramaya University and graduated with BSc degree in Soil and Water Engineering Management in July, 2006.

The author was firstly employed as a Soil and Water Conservation expert and worked for 2 months, in North wollo zone, Wadila district. From Nov, 2006 to July, 2009; he was working as a Soil and Water Conservation expert, in North wollo, Habru District Agricultural and Rural Development Office.

Since then, he has been working in Sirinka Agricultural Research Centre as an Agricultural Water Management researcher.

In October 2013, he was joined to the School of Graduate studies of Arba Minch University for his M.Sc. study under Water Resource and Irrigation Engineering program /Irrigation and Drainage Engineering/.

ACKNOWLEDGEMENTS

First of all, I must thank the Almighty God who helped me starting from the earlier to the end of this journey. It was amazing and marvelous year '2007E.C' for me. Thanks my God!!!

I would like to express my gratitude to my instructor and advisor Dr. Zeleke Agide for his guidance and assistance throughout the course of this work. I feel deeply indebted to express my special gratitude to my Co-advisor Dr. Yigzaw Desalegn for his heart-full and unreserved support, and day to day follow up and encouragement. His insightful comments for the betterment of the whole work were appreciable. Without his assistance this work would have been more difficult.

I would also like to thanks Dr. Amare Hailelassie for his comments and material support during proposal preparation period. My particular gratitude goes to International Livestock Research Institute (ILRI); LIVES project for funding this research work and Sirinka Agricultural Research Center (SARC) for gave me a leave of absence for this study.

I would like to express my heartfelt gratitude to my mother 'Bayush Yimer'; this fruit is the seed she sowed with long time effort. My gratitude goes to my brother Fentaw Ale and my sister Serke Zinabe for their moral support and encouragement.

I would like to extend my sincere thanks to my staffs Abera Getnet, Gebeyaw Molla, Amare Alemnew and our driver Habtemaria Assefa, for their heart-full support during filed survey works. Also to Zeleke Belay and Sisay Desalegn for their moral support and facilitating laboratory works. I would like to thanks Tizazu Yitayew, Hawa Fentaw (Jari kebele 13 Irrigation expert) and Mekonen Gebre (Kebele 08 irrigation Expert) for their support.

I gratefully acknowledged my heartfelt friend Mesfin Kebede for his moral support and takeover of my personal tasks behalf of me. And also thanks my best friend Yonas Moges for his encouragements.

I feel great pleasure to express my special gratitude to MY BELOVED girl friend **Hable Mulugeta**. I have no words to appreciate for her moral support, encouragement, strengthen and patience paying for our love and relationship during my tiresome course period. I always love her!!!

ACRONYMS

a.s.l	above sea level
AE	Agronomic Efficiency
ARDO	Agricultural and Rural Development Office
BoWR	Bureau of Water Resource
Ec	Conveyance Efficiency
ETo	Reference Evapo-transpiration
FAO	Food and Agricultural Organization
FUE	Fertilizer Utilization Efficiency
GPS	Global Positioning System
GRI	Gross Return on Investment
Ha	Hectare
HH	Household
ILRI	International Livestock Research Institute
IR	Irrigation ratio
IWMI	International Water Management Institute
IWUAs	Irrigation Water user associations
L	Losses
LIVES	Livestock and Irrigation Value Chains for Ethiopian Smallholders
LSI	Large Scale Irrigation
Mha	Million Hectare
MoWR	Ministry of Water Resources
MSI	Medium Scale Irrigation
NGOs	Non-Governmental Organizations
O & M	Operation and Maintenance
OPUCA	Output per Unit Command Area
OPUIA	Output per Unit Irrigated Cropped Area
OPUID	Output per Unit Irrigation Water Delivered
OPUIS	Output per Unit Irrigation Water Supply
OPUWC	Output per Unit Water Consumed
ORDA	Organization for Rehabilitation and Development in Amhara
PFP	Partial Factor of Productivity
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SIA	Sustainability of irrigated area
SSI	Small Scale Irrigation
WUA	Water User Association
OM	Organic Matter
N	Total Nitrogen
P	Available Phosphorous

TABLE OF CONTENTS

Declarations	I
Approval page.....	ERROR! BOOKMARK NOT DEFINED.
Dedication	III
Biographical sketch.....	IV
Acknowledgements.....	V
Acronyms.....	VI
List of tables.....	X
List of figures.....	XII
<i>Abstract</i>	XV
CHAPTER ONE	1
1. INTRODUCTION.....	1
1.1. BACKGROUND	1
1.2. STATEMENT OF THE PROBLEM	4
1.3. OBJECTIVE OF THE STUDY.....	5
1.4. RESEARCH QUESTIONS.....	5
1.5. SIGNIFICANCE OF THE STUDY.....	5
1.6. SCOPE OF THE STUDY	6
1.7. ORGANIZATION OF THE THESIS	6
CHAPTER TWO	7
2. LITERATURE REVIEW.....	7
2.1. SUMMARY OF IRRIGATION	7
2.2. COMPONENTS OF IRRIGATION SYSTEM	8
2.2.1. <i>Irrigation scheme</i>	8
2.2.2. <i>On-farm management</i>	9
2.2.2.1. <i>Irrigation water management</i>	9
2.2.2.2. <i>Fertilizer utilization</i>	12
2.2.3. <i>Organizations</i>	14
2.3. TYPES OF IRRIGATION SCHEMES.....	14
2.3.1. <i>Small scale irrigation scheme</i>	15
2.3.2. <i>Medium scale irrigation scheme</i>	16
2.3.3. <i>Large scale irrigation scheme</i>	16
2.4. IRRIGATION SCHEME PERFORMANCE ASSESSMENT.....	16
2.4.1. <i>Importance of performance assessment</i>	16
2.4.2. <i>Factors affecting the performance of irrigation schemes</i>	17
2.4.3. <i>Performance assessment methods</i>	17
2.4.3.1. <i>Process performance assessment</i>	18
2.4.3.2. <i>Comparative performance assessment</i>	19
2.4.4. <i>Performance indicators</i>	19
2.4.5. <i>Features of comparative performance indicators</i>	21
2.4.6. <i>Selected performance indicators</i>	22
2.4.6.1. <i>Water delivery indicators</i>	22
2.4.6.2. <i>On-farm Water management indicators</i>	24
2.4.6.3. <i>Physical performance indicators</i>	28
2.4.6.4. <i>Financial indicators</i>	28
2.4.6.5. <i>Organizational indicators</i>	28
2.5. CONCLUDING REMARK	31

CHAPTER THREE	32
3. MATERIALS AND METHODS	32
3.1. DESCRIPTION OF THE STUDY AREA.....	32
3.1.1. <i>Tehuledere district</i>	32
3.1.2. <i>Jari small scale irrigation scheme</i>	33
3.1.3. <i>Aloma small scale irrigation scheme</i>	34
3.2. DATA COLLECTION AND ANALYSIS	35
3.2.1. <i>Data collection methods</i>	35
3.2.1.1. Primary data collection	36
3.2.1.2. Secondary data collection	44
3.2.2. <i>Data Analysis Techniques</i>	44
3.2.2.1. Determination of crop water and irrigation water requirement.....	44
3.2.2.2. Irrigation scheduling	45
3.2.2.3. Performance indicators	46
CHAPTER FOUR	54
4. RESULTS AND DISCUSSION	54
4.1. STATUS OF IRRIGATION SCHEMES AND IRRIGATION PRACTICES	54
4.1.1. <i>Jari small scale irrigation scheme</i>	54
4.1.2. <i>Aloma small scale irrigation scheme</i>	55
4.2. CHARACTERISTICS OF THE IRRIGATION SCHEMES BENEFICIARIES.....	56
4.3. FACTORS AFFECTING IRRIGATED CROP PRODUCTION.....	57
4.4. RAINFALL DATA ANALYSIS	58
4.5. DETERMINATION OF REFERENCE EVAPO-TRANSPIRATION (ET _o)	60
4.6. CROPPING PATTERN OF THE IRRIGATION SCHEMES.....	60
4.7. SOIL DATA ANALYSIS RESULTS.....	62
4.7.1. <i>Soil textural class and nutrient contents</i>	62
4.7.2. <i>Soil field capacity and permanent wilting point</i>	63
4.7.3. <i>Soil infiltration rate</i>	64
4.8. DETERMINATION OF CROP WATER REQUIREMENTS AND IRRIGATION REQUIREMENTS	65
4.9. WATER FLOW RATE MEASUREMENT	68
4.9.1. <i>Flow rate measurement at Jari SSI Scheme</i>	68
4.9.2. <i>Flow rate measurement at Aloma SSI scheme</i>	71
4.9.3. <i>Water flow rate measurement at farm inlets</i>	72
4.10. IRRIGATION SCHEDULING	74
4.11. ESTIMATION OF TOTAL OUTPUT PRODUCTION.....	78
4.12. COMPARISON OF THE TWO SMALL SCALE IRRIGATION SCHEMES.....	80
4.12.1. <i>Water delivery indicators</i>	80
4.12.1.1. Conveyance efficiency.....	80
4.12.1.2. Relative water supply.....	85
4.12.1.3. Relative irrigation supply.....	86
4.12.2. <i>On-farm water management indicators</i>	88
4.12.2.1. Agricultural output indicators	88
4.12.2.2. Fertilizer utilization efficiency indicators	92
4.12.3. <i>Physical performance indicators</i>	95
4.12.3.1. Irrigation ratio	95
4.12.3.2. Sustainability of irrigated area	96
4.12.4. <i>Financial indicator</i>	97

4.12.4.1.	Gross return on investment	97
4.12.5.	<i>Organizational indicators</i>	98
4.12.5.1.	Organizational structures of WUAs	99
4.12.5.2.	Bylaws.....	101
4.12.5.3.	Fee collection	102
4.12.5.4.	Degree of participations of users in operation and maintenance	103
4.12.5.5.	Water allocation and water distributions.....	104
4.12.5.6.	Conflicts and conflict managements	106
CHAPTER FIVE	108
5. CONCLUSIONS AND RECOMMENDATIONS	108
5.1. CONCLUSIONS	108
5.2. RECOMMENDATIONS	110
References.....		111
List of appendix tables.....		119
List of appendix figures		134

List of Tables

Table 2.1: Selected FUE terms and their applications; after (Dobermann, 2007).....	13
Table 2.2: PFP and AE levels for cereal crops (primarily maize, rice, and wheat).....	26
Table 2.3: PFP for N applied to cereals for world regions and associated average fertilizer N rates and crop yields.....	27
Table 2.4: PFP and AE values for N for maize, wheat, and rice	27
Table 3.1: Yield samples of main crops at both irrigation schemes	37
Table 4.1: Socio-demographic characteristics of beneficiary household heads	56
Table 4.2: Farmers rank of factors affecting irrigated crop production at Jari and Aloma irrigation schemes	58
Table 4.3: Farmers crop selection criteria.....	61
Table 4.4: Crops area coverage and LGP at Jari and Aloma SSI schemes.....	61
Table 4.5: Soil textural classes of the irrigation schemes	62
Table 4.6: Soil OM and total N contents at Jari and Aloma SSI schemes.....	63
Table 4.7: Soil available phosphorous analysis results.....	63
Table 4.8: Soil FC, PWP and TAM of the irrigation schemes	64
Table 4.9: FAO recommended infiltration value for basic soil types.....	65
Table 4.10: Crop water and IR of Jari and Aloma irrigation schemes	67
Table 4.11: NCWR and NIR per season for Jari and Aloma SSI schemes	68
Table 4.12: Respondents evaluation on length of months to access irrigation water	69
Table 4.13: Mean flow rate at the diversion site of Jari and Aloma irrigation schemes ...	70
Table 4.14: Mean flow rate, CE and losses at the main and secondary canals of Jari.....	71
Table 4.15: Mean flow rate, CE and L at the main and secondary canals of Aloma.....	72
Table 4.16: Mean command area, discharge rate and duration of irrigation at Jari and Aloma SSI schemes	73
Table 4.17: Computed values of diverted and delivered volume of water for Jari and Aloma SSI schemes	73
Table 4.18: Irrigation interval practiced by farmers in Jari and Aloma irrigation schemes.....	75
Table 4.19: Computed irrigation intervals at each growth stage and irrigation frequencies.....	76
Table 4.20: Crop yields and output production values for Jari SSI scheme.....	78
Table 4.21: Crop yields and output production values for Aloma SSI scheme.....	79

Table 4.22: Parameters for agricultural performance indicators	88
Table 4.23: Crop yields, and nitrogen and phosphorus fertilizer rates at both schemes....	92
Table 4.24: Computed values of PFP and AE for N and P fertilizer rates	93
Table 4.25: Basic parameters and computed values of IR and SIA.....	95
Table 4.26: Investment cost of the irrigation systems	98
Table 4.27: Perceptions of respondents on the maintenance condition of irrigation infrastructures	103
Table 4.28: Respondent’s observation on location of structural failure	104
Table 4.29: Main criteria used to scheduling irrigation.....	105
Table 4.30: Levels of water distribution.....	105
Table 4.31: Reasons for unfair distribution of water	105
Table 4.32: Beneficiaries response on conflict over irrigation water	106
Table 4.33: Causes of conflicts over irrigation water	107

List of Figures

Figure 2.1: The three main constitutes of irrigation schemes /Source: Lemperiere <i>et al.</i> (2014)/	8
Figure 2.2: The six main sub constituents of irrigation scheme /source: Lemperiere <i>et al.</i> (2014)/	9
Figure 3.1: Location map of the study areas.....	32
Figure 3.2: Flow chart of methodology adopted in the present study	36
Figure 3.3: Layouts for water flow rate measurement points (not scaled)	39
Figure 3.4: Water flow rate measurement trough current meter.....	40
Figure 3.5: Canal flow cross section.....	40
Figure 4.1: Jari SSI scheme mean monthly rainfall, effective rainfall and ETo values ...	59
Figure 4.2: Aloma SSI scheme mean monthly rainfall, effective rainfall and ETo values	59
Figure 4.3: Net scheme irrigation requirement at both schemes	66
Figure 4.4: Weekly and monthly flow rate variations at Jari intake.....	70
Figure 4.5: Weekly and monthly flow rate variations at Aloma intake.....	72
Figure 4.6: Water availability and demand of Jari SSI scheme.....	74
Figure 4.7: Water availability and demand of Aloma SSI scheme.....	74
Figure 4.8: Mean inflow, outflow and CE at the main canal in Jari and Aloma	81
Figure 4.9: Mean water losses at the main canal of Jari and Aloma irrigation schemes ...	81
Figure 4.10: Cracked and fractured secondary canals at Aloma	83
Figure 4.11: Secondary canals (silted, buried and over topped) at Jari SSI	83
Figure 4.12: Over all water delivery conveyance efficiency at Jari and Aloma.....	85
Figure 4.13: RWS and RIS indicators.....	86
Figure 4.14: OPUIA and OPUCA (\$/ha) values at both irrigation schemes	89
Figure 4.15: Computed values of OPUIS, OPUID and OPUWC (\$/m ³) at both irrigation schemes	89
Figure 4.16: Irrigation ratio and sustainability of irrigated area at Jari and Aloma.....	96
Figure 4.17: WUAs organizational structure and organizational levels	101

List of Appendix Tables

Appendix table 1: Mean monthly rainfall and effective rainfall (USDA SCS method) for Jari irrigation scheme	119
Appendix table 2: Mean monthly rainfall and effective rainfall (USDA SCS method) for Aloma irrigation scheme	119
Appendix table 3: Mean monthly meteorological data and ETo values of Jari irrigation scheme	119
Appendix table 4: Mean monthly meteorological data and ETo values of Aloma irrigation scheme	120
Appendix table 5: Yield samples for major crops at each SSI scheme	120
Appendix table 6: Crops area coverage and planting date at Jari and Aloma SSI schemes	121
Appendix table 7: Monthly net scheme irrigation requirements of a given cropping pattern	121
Appendix table 8: Jari weekly flow variations at intake	122
Appendix table 9: Jari monthly flow variations at intake	122
Appendix table 10: Aloma weekly flow variations at intake	122
Appendix table 11: Aloma monthly flow variations at intake	122
Appendix table 12: Main canal conveyance efficiency and losses at Jari	122
Appendix table 13: Main canal conveyance efficiency at Aloma SSI scheme	124
Appendix table 14: Secondary canal conveyance efficiency at Jari SSI scheme	125
Appendix table 15: Secondary canal conveyance efficiency at Aloma SSI scheme	125
Appendix table 16: Volume of water distributed along the canal reaches at Jari	126
Appendix table 17: Volume of water distributed along the canal reaches at Aloma	126
Appendix table 18: Crops characteristic data for Jari SSI scheme	127
Appendix table 19: Crops characteristic data for Aloma SSI scheme	129
Appendix table 20: Chick pea irrigation requirement at Jari SSI scheme	130
Appendix table 21: Chick pea crop irrigation scheduling at Jari SSI scheme	130
Appendix table 22: Onion irrigation requirement at Jari SSI scheme	130
Appendix table 23: Onion crop irrigation scheduling at Jari SSI scheme	131
Appendix table 24: Teff irrigation requirement at Aloma SSI scheme	131
Appendix table 25: Teff crop irrigation scheduling at Aloma SSI scheme	132
Appendix table 26: Potato irrigation requirement at Aloma SSI scheme	132

Appendix table 27: Potato crop irrigation scheduling at Aloma SSI scheme.....	133
Appendix table 28: Questionnaires for the Evaluation of Jari and Aloma Small Scale Irrigation Schemes	140
Appendix table 29: Focus Group discussion checklist	147

List of Appendix Figures

Appendix figure 1: Determination of soil textural class	134
Appendix figure 2: Field soil infiltration rate test	134
Appendix figure 3: Soil infiltration rate graph at Jari.....	135
Appendix figure 4: Soil infiltration rate graph at Aloma.....	135
Appendix figure 5: Water flow rate measurement through Cut-Roat Flume	136
Appendix figure 6: Water stressed Teff crops at Jari SSI scheme.....	136
Appendix figure 7: Main canal water losses at Aloma SSI schemes (on earthen canal). 137	
Appendix figure 8: Water losses in main canal (water transmitting flume).....	137
Appendix figure 9: Local water control and canal breaching.....	138
Appendix figure 10: Damaged cut-off drains at Jari SSI scheme.....	138
Appendix figure 11: Flooding irrigation for potato crops at Aloma SSI scheme.....	139
Appendix figure 12: House hold survey and team of interviewers	139

ABSTRACT

Irrigation scheme performance assessment is vital to evaluate the impacts of irrigation practices, to identify performance gaps and to improve system performances. However, the performance of Jari and Aloma Small Scale Irrigation (SSI) schemes was not assessed since its operation. Therefore, this study was carried out to evaluate the water delivery, on-farm water management and organizational performances of the two SSI schemes. Secondary data from different reports and primary data through field measurements, household surveys, key informant interviews and group discussions were collected. CROPWAT 8.0 model, SPSS and GIS software were used to analyze the data. The result of this study revealed that, the overall canal water delivery efficiencies of Jari and Aloma SSI schemes were 66% and 59%, respectively. Majority of the respondents, 37% in Jari and 61.9% in Alom, reflected that the maintenance condition of irrigation infrastructures was bad. From the respondents 45.5% in Jari and 50% in Aloma described that illegal water abstraction accounts the primary cause for unfair water distributions. The ratios of relative water supply and the relative irrigation water supply were almost equal to 1 at both SSI schemes. This implied that the amount of water supplied was sufficient for the water demand of the schemes. Output per unit irrigated area values of 2198\$/ha and 1356\$/ha were calculated at Jari and Aloma SSI schemes, respectively. Furthermore, the output per unit command area of Jari (3464\$/ha) was three fold higher than the value of Aloma (1061\$/ha). Water productivity indicators such as, Output per unit irrigation water supplied (OPUIS), Output per unit irrigation water delivered (OPUID) and Output per unit water consumed (OPUWC) values of 0.47\$/m³, 0.89\$/m³ and 0.49\$/m³ in Jari, and 0.2\$/m³, 0.55\$/m³ and 0.3\$/m³ in Aloma schemes were calculated, respectively. Irrigation intensity ratio in Jari (174%) was much higher than Aloma (78%). The original irrigable areas were declined by 14% in 3 years and 39% in 10 years operation periods in Jari and Aloma schemes, respectively. The main reasons for low output production in Aloma scheme were low irrigation intensity, grown low value crops. Generally the performance of Jari is better than Aloma SSI schemes.

Key words; SSI scheme, performance, efficiency, water, land, output, irrigation

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Ethiopia is one of few African countries endowed with abundant water resources. The country has 12 river basins with an annual runoff volume of 124 billion meter cube (BMC) of water and an estimated ranges of 2.6 BMC to 30 BMC ground water potential (EPCC, 2015). The irrigation potential is also estimated about 5.3 Mha from 15 Mha of total cultivated area. The irrigation area of the country is 640,000 ha. Of these 120,000 ha using rain water harvesting, 383,000 ha from small scale irrigation and 129,000 ha from medium and large scale irrigation systems (Awulachew *et al.*, 2010a; EPCC, 2015).

Amhara region is one of the regions which have abundant water resources in Ethiopia. The annual runoff in the region is estimated to be 60 billion m³ with water resources per capita of 3,570 m³ (Melkamu, 1996). A region has three river basins, namely the Abbay, Tekezze and Awash drainage basins. In addition Anghereb, Mille, Kessem and Jema are among the major national rivers, which are found in this region. This region is one of the regions in the country with vast potential for irrigation development. Estimated potential land for large and medium scale irrigation of the region is about 650,000 - 700,000 ha and for small scale irrigation is about 200,000 - 250,000 ha, indicates the magnitude of water resources available for development (BCEOM, 1999).

The study site is located within Upper Mile River sub basin, which is a tributary to Awash River basin and endowed with different water sources. According to Agricultural and Rural Development Office annual report, Tehuledere district has a cultivable land of 16,133ha and an irrigable land of 7,300ha and from this 6,670ha was irrigated in the irrigation season; included house hold level water storage ponds; but due to data collection and recording gaps the reliability of the figure exaggerated (Annual report of ARDO, 2014).

Agriculture is predominantly rain fed and the country has experienced chronic food insecurity due to degradation of the natural resource base, and also frequent droughts (Devereux, 2000). The problem of food security is also aggravated by the rapid growth of population and hence of the demand for food. Central Statistical Agency of Ethiopia (2007) predicted that the population of Ethiopia and specifically the Amhara region will

be reached to 94.4 and 21.2million by the end of 2017 in the medium case scenario, respectively.

Furthermore, the country could not meet its large food deficits through relying on rain-fed agriculture alone. To overcome the effects, there is a growing interest in the promotion of water-centered development. At present there are efforts underway to change this situation to reduce dependency on rainfall, through the introduction of various irrigation systems. According to a *Growth and Transformation Plan I, 2010/11-2014/15*; the irrigation sector development program stipulate to develop additional 746,335ha of land to achieve a total irrigated land of 1.85 Mha at the end of planning period (MoFED, 2010). According to Ministry of Agriculture (MoA, 2015) annual report about 2.4Mha area were irrigated up to the end of 2014/15 fiscal year; i.e. the actual achievement is beyond the planned one.

Agriculture is the main water user but information on agricultural water use is nonexistent. Predominantly no reliable data on the area of small-scale irrigation are available and most irrigation infrastructures are not effectively used. Because, the performance of many irrigation systems is significantly under their potential due to a number of shortcomings, such as poor design and construction, operation and maintenance (sedimentation impacts and small holders' limited skills in operation and maintenance), sustainability of irrigation area, water delivery performance and watershed managements (Awulachew et al., 2010b).

However sustainable production increase can be achieved by two ways in irrigated agriculture; either new irrigation projects can be developed or existing schemes can be evaluated and their performance can be improved. In Ethiopia water resources are huge and untapped but low economy of the country not much attractive to develop new irrigation schemes. Therefore improving the existing irrigation schemes followed by constructing additional new irrigation schemes is more preferable for sustainable development of the country.

The World Bank, other development banks and numerous countries have invested in large irrigation projects. There have been conflicting opinions about the wisdom of investing further in new irrigation projects, primarily due to the questions about the performance of existing projects (Burt and Styles, 1999).

In recent years improving irrigation systems performance is more preferable than developing new irrigation schemes due to investment in irrigation has failed to produce the expected result in many countries. According to Luis (1999) field evaluation play a fundamental role in improving irrigation systems. Awulachew *et al.* (2010a) reported that improving low-performing schemes specifically small scale irrigation schemes requires incorporating applied research on irrigated agriculture. Performance evaluation result provides the information required for design, model validation, and mainly for advising irrigators on how to improve their systems and management practices.

Irrigated agriculture is a complex that is influenced by weather, labor, irrigation scheduling, on-farm water managements, farming practices / agronomic, crop selection, cropping pattern, soil fertility/, the availability and management of inputs /fertilizers, chemicals etc...), equity, cost recovery, marketing and organizational aspects.

Crop production can also be increased through close linking of both inputs of water and nutrients; plant nutrients and water are complementary inputs. Where current crop yields are far below their potential, improvements in soil and nutrient management can generate major gains in water use efficiency (Molden, 2007). Moreover sustainability is not just the problem of technology and natural resources alone; it is also human, social (institutional and organizational) problem. Adequate institutionalization and organizational development is crucial to enhance management and sustainability of the irrigation systems.

Performance assessment across an organization covers a wider range of performance indicators. Generally IWMI developed two types of indicators to evaluate irrigation systems: process /internal/ and comparative /external/ indicators. The aim of applying comparative indicators is to evaluate outputs and impacts of irrigation management practices, interventions across different systems and system levels, as well as to compare various irrigation seasons and technologies with one another while process indicators are used to assess actual irrigation performance relative to system specific management goals and operational target (Kloezen *et al.*, 1998).

Evaluating and improving the performance of the existing schemes is an attractive way for sustainable development and used as a bench mark or point of entry for further irrigation development.

1.2. Statement of the Problem

In Ethiopia, scheme performance is estimated 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., 2010a; 2010b). The interventions so far made in Amhara region focuses on the development of new irrigation schemes and upgrading the physical infrastructures of existing traditional irrigation schemes. Yakob and Melaku (2006) reported that the performance of many irrigation schemes in Amhara region is far below their potential mainly due to inefficient irrigation water management, poor maintenance and problems associated to input supply and marketing.

Poor management of available water for irrigation, both at system and farm level has led to a range of problems and further aggravated water availability and has reduced the benefits of irrigation investments (FAO, 1996). Additionally poor soil fertility limits the ability of plants to efficiently use water (Bossio *et al.*, 2008).

Particularly in South Wollo zone little or no attention is given to the monitoring and evaluation of the performance of already established irrigation schemes. Tehuledere District is one of the areas in South Wollo Zone, where erratic rainfall and moisture stress problems are frequently observed. To cope up the problems around 28 small scale irrigation schemes were constructed in different years. From those, Jari and Aloma small scale irrigation schemes cover an area of 146 and 115ha respectively.

Jari SSI scheme was constructed with large investment cost and contains alternative water sources from night storage and rainwater harvesting ponds. Jari and Aloma SSI schemes have been giving service for 10 and 3 years respectively. However the schemes have not been fully functional as expected and their performances are under utilization and the structures are under failure. More generally there are many factors accountable for the poor performance of irrigation schemes at the existing conditions.

Despite the poor performance of the irrigation schemes in the district, evaluation of small-scale irrigation schemes and benchmarking of the results is not common; this is particularly true in using the *comparative performance indicators*. This study aim was to undertake a comparative performance evaluation of Jari and Aloma SSI schemes.

1.3. Objective of the Study

The general objective of this study was to undertake comparative performance evaluation on two small-scale irrigation schemes of Tehuledere district, Ethiopia.

Specific Objectives

- i. To evaluate the water delivery performance of Jari and Aloma small scale irrigation schemes with comparative performance indicators.
- ii. To evaluate the on-farm water management performance of Jari and Aloma small scale irrigation schemes with comparative performance indicators.
- iii. To evaluate organizational setups and performances for irrigation water management and scheme maintenance.

1.4. Research Questions

1. What are the main factors which affects the water delivery performances of the irrigation schemes?
2. What are the main constraint problems that affect land and water productivity and how is the level of land and water productivity at both irrigation schemes?
3. What are the main out puts and impacts existed due to the intervention of irrigation schemes at scheme and across system levels?
4. How is the irrigation scheme organization contributed for the management and sustainability of the schemes?

1.5. Significance of the Study

This study will provide information for the performance or productivity of the current irrigation schemes. The study shall have significant contribution to understand the draw backs and best achievements across system levels. And also will give insights the impacts of intervention and directions for policy makers. It will gives information for further improvement and investment approaches for implementing agents (GOs, NGOs, research centers, contractors, etc...). It also used as a benchmark and entry point for development works and future studies.

1.6. Scope of the Study

The study was conducted on two small scale irrigation schemes of Tehuledere district.

The expected out puts of this research were:

- ❖ Document the performance of two irrigation schemes in terms of water delivery and on-farm water management.
- ❖ Document existing organizational arrangements and their impacts on irrigation water managements.
- ❖ Recommendations to improve the performance of irrigation schemes and list of best experiences from each scheme for scale up.

1.7. Organization of the Thesis

The organization of the thesis totally contains five chapters. Chapter one includes background, statement of the problem, 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.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Summary of Irrigation

Irrigation is the application of water to agricultural crops by artificial means, designed to permit farming in arid and semi arid regions and helped to increase agricultural production in developing countries (FAO, 1995). Thus irrigation development particularly will be an important component of diversification and expansion strategy to strengthen food security in the future. However irrigation project development has both positive and negative impacts in the society and environment.

Irrigated agriculture can be considered as sustainable if it is every time achieves high productivity without damaging the physical and social environment owning to its excellent design and management are in place. Some of the positive impacts are; better management of scarce natural resources of water and land, creating longer growing season, allowed to double cropping, higher yield per unit land, higher yield per unit water, accessed employment, enhanced farm income, improve standard of living, Secure food self sufficiency, increase well being of the society, resilience against drought, and contributed to gross national product (GNP).

Beside this, other projects caused serious damage to the environment like salinity and water logging, and in some instances aggravating community problems, because of different reasons such as social conflicts, the opportunities for propagation of aquatic disease vectors (e.g. malaria mosquito, schistosomiasis snail) and water hyacinth. In other areas the fertile soil has been removed from annual production by flooding and erosion. If wise utilization and management strategies are not properly implemented; the future base of the existing and the coming generation, particularly the land and water resources have been at risk alarmingly.

2.2. Components of Irrigation System

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

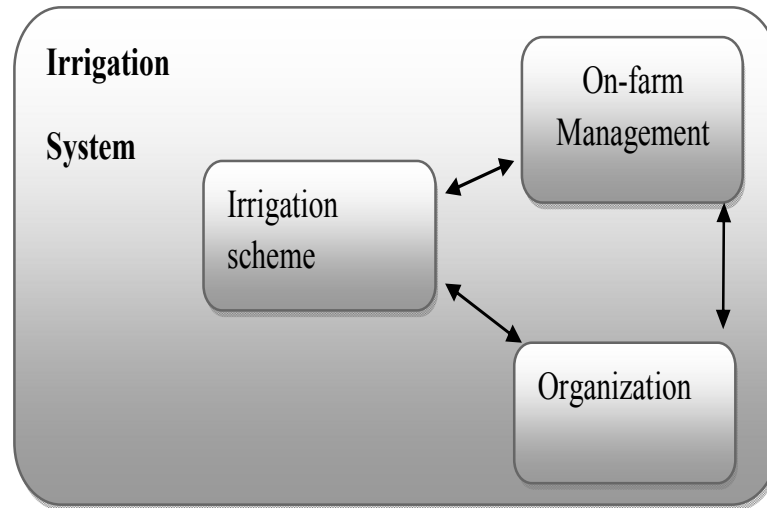


Figure 2.1: The three main constituents of irrigation schemes /Source: Lemperiere *et al.* (2014)/

2.2.1. Irrigation scheme

It is the Characteristics of the irrigation infrastructures and equipments (intake, canals and drainage ditches, water partition structures, etc.) and the irrigated area. Farmers and their organizations have to take into account the technical, organizational and financial constraints related to O&M of their irrigation scheme. The irrigation scheme has two main sub-constituents of land and water constituents. To ensure the cohesion of the irrigation scheme, there should be close link between the “land constituent” and the “water constituent” at different levels.

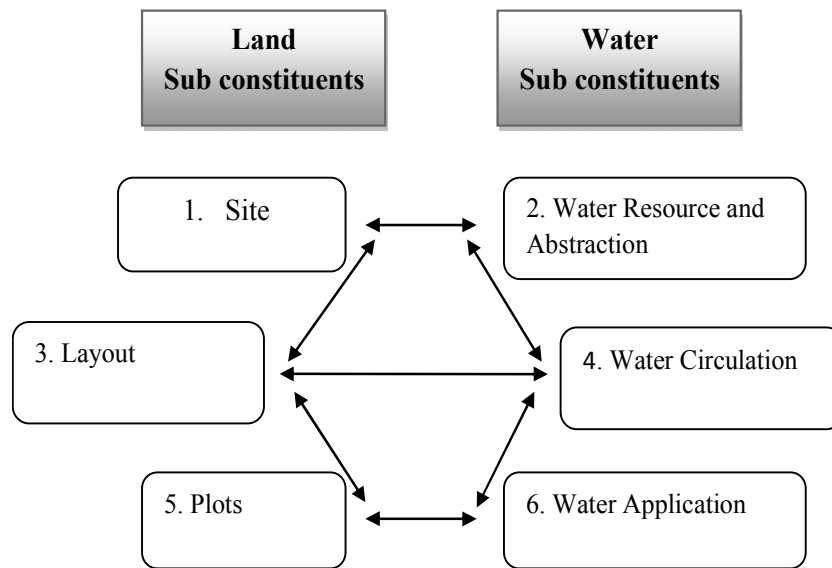


Figure 2.2: The six main sub constituents of irrigation scheme /source: Lemperiere *et al.* (2014)/

2.2.2. On-farm management

On-farm management refers to the landholdings and the production process of individual farmers. It results from choices and decisions made by farmers. The heads of the farming household make decisions regarding the selection of crops, and the allocation of labor, inputs and capital with due considerations to the constraints they face and the opportunities they want to use.

Generally irrigated agricultural production at farm level, which includes the type of crops, agricultural technologies, allocation of labor inputs and capital (farming tools, oxen, etc.), in the production process. The characteristics of “on-farm management” are: land holding, production processes, agricultural technologies, economic outputs and categorization of farmers.

2.2.2.1. Irrigation water management

On-farm irrigation systems and operations need to be measured to determine the potential efficiency of the systems as designed and the actual efficiency that is obtained with present management (Merriam *et al.*, 1983). According to U.S Bureau of Reclamation (2005), “Irrigation Water Management” means management of irrigation water on the farm through the act of timing and regulating irrigation water application in a way that will satisfy the water requirement of the crop without washing water, soil and plant

nutrients and degrading the soil resource. The objectives of any irrigation system are to deliver irrigation water in the right amount (size, frequency, and duration), at the right place, at the right moment. Management activity is a major component of success for any irrigation scheme (Depeweg, 1999).

A good management, proper and timely application of water may result in better yield and reduction in drainage problems. Farmers are not sure when and how much water they can expect, which leads to very little cooperation and involvement in irrigation management, and limited contribution by term to operation and maintenance costs (Wil, 1994). Irrigation scheduling (amount, frequency and duration of irrigations); have significant effects on crop yield and farm productivity. Crops differ in their structures and habits, thus their water requirements vary widely.

Irrigation scheduling

Irrigation scheduling is the process or planning of determining when to irrigate and how much water to apply per irrigation in order to maintain healthy plant growth during the growing season. Proper timing or scheduling of irrigation water applications is a crucial decision for a farm manager to:

1. Allows irrigations to be coordinated with other farming activities including cultivation and chemical applications,
2. Meet the water needs of the crop to prevent yield loss due to water stress,
3. Maximize the irrigation water use efficiency resulting in beneficial use and conservation of the local water resources,
4. Minimize the leaching potential of nitrates and certain pesticides that may impact the quality of the groundwater.
5. Improve crop yield and/or quality, water and energy conservation, and lower production costs.

Inflexible delivery (i.e., rigid-rotation delivery schedules or irrigation season restricted to a certain period in the year) limits the type of crops that can be grown and constrains agronomic practices. Effective irrigation is possible only with regular monitoring of soil water and crop development conditions in the field, and with the forecasting of future crop water needs.

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. However, it is often sufficient to estimate the irrigation schedule and to fix the most suitable depth and interval: to keep the irrigation depth and the interval constant in the growing stages.

Irrigation interval is the length of time in days between two consecutive irrigation applications. When crop is sensitive to water stress, delayed water application would affect yield, which cannot be compensated by over irrigation. Interval between irrigation has pronounced effect on yields, with higher yields being achieved when intervals are kept shorter.

Under conditions of limited water supply, total production will be higher when full crop water requirements are met over a limited area than when crop water requirements are partially met over an extended area (FAO, 2012). Irrigation interval depends on water depletion requirements of the crop, rooting depth, soil type and growth stage of the crop. The total available water (TAW) is the difference between field capacity and wilting point contents multiplied by the depth of the root zone (Z_r), (Allen *et al.*, 1998).

$$TAW = (F_c - PWP) * Z_{eff} \dots \dots \dots [2.1]$$

Where;

TAW= is total available soil moisture (mm);

F_c= is volumetric moisture content at field capacity soil (m³/m³),

PWP= is volumetric moisture content at permanent wilting point (m³/m³),

Z_{eff}= Effective root zone of a crop (mm).

Only a portion of the total soil water is readily available for plant use. Plants can only extract a portion of the stored water without being stressed. An availability coefficient is used to calculate the percentage of water that is readily available to the plant. The maximum soil water deficit (MSWD) (also referred to as the management allowable deficit) is the amount of water stored in the soil that is readily available to the plant. The depletion amount is depending on crop types and growth stages of the specific crop. The crop should be irrigated once this amount of moisture has been removed from the soil.

Once depleted this is the amount that must be replenished by irrigation. It is also the maximum amount that can be applied at one time, before the risk of deep percolation occurs (WCFS, 2002).

$$RAW = TAW * P \dots \dots \dots [2.2]$$

RAM= readily available water (mm)

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

I= irrigation interval (days)

ETc= Crop water requirement (mm/day)

$$I = \frac{RAW}{ETc} \dots \dots \dots [2.3]$$

2.2.2.2. Fertilizer utilization

There is a need to increase productivity of agriculture to keep pace with population growth to ensure adequate supply of food in the future. The world’s cultivated area has grown by 12% over the last 50 years. Over the same period, the global irrigated area has doubled, accounting for most of the net increase in cultivated land (FAO, 2011), and world fertilizer use has increased more than fivefold (IFA, 2014). Driven by the fast expansion of irrigation and fertilizer consumption and the adoption of improved seeds and best management practices, which triggered a significant increase in the yields of major crops, agricultural production has grown between 2.5 and 3 times since the beginning of the 1960s (FAO, 2011). Globally, fertilizer demand is projected to continue rising. It is forecast to reach about 200 Mt towards 2020 (Heffr and Prud’homme, 2014).

Ethiopian government has embarked to promote the use of improved crop production technologies, a key component of which is chemical fertilizers. In contrast, there are still large areas where farmers use little fertilizer and mine their soil nutrient reserves. This is particularly a case in sub-Saharan Africa, where farmers are estimated to have used 11 kg nutrients/ha in 2013, i.e. only 10% of the global average, but the region has witnessed the strongest growth rate since 2008 (FAO, 2011). Particularly the adoption and intensity of fertilizer application by Ethiopian small holder farmers are remained very low despite government efforts to promote its use. Still the application rates remain far below the recommended level.

Plant nutrients alone, are not sufficient to grow or sustain plant growth without water, and vice versa. Water and nutrient use within plants are closely linked. Wise management of water, fertilizer, and soil is critical in sustainable food production. Thus, even in dry environments, where water appears to be the limiting factor for plant growth, irrigation alone may fail to boost yields without consideration of the soil and its nutrient status. A plant with adequate nutrition can generally better withstand water stress (Waraich *et al.*, 2011). As a result it is a principal issue of considering or evaluating nutrient/fertilizer utilization efficiencies (NUE/FUE) in crop production systems. The effectiveness is highly influenced by fertilizer management and plant-soil-water managements.

The key objective of applying nutrient is to increase performance of cropping systems by applying economically optimum to the plant with minimum losses from field. Dobermann (2007) showed a number of ways how to estimate and measure NUE/FUE/ in different ways.

Table 2.1: Selected FUE terms and their applications; after (Dobermann, 2007)

Term	Calculation	Question addressed	Typical use
Partial factor of productivity	$PFP = \frac{Y}{F}$	How productive is this cropping system in comparison to its nutrient input?	As a long-term indicator of the trend
Agronomic efficiency	$AE = \frac{Y - Y_0}{F}$	How much productivity improvement was gained by use of nutrient input?	As a short-term indicator of the impact of applied fertilizer on productivity. Also used as input data for fertilizer recommendations based on omission plot yields.

Where;

Y = yield of harvested portion of crop with fertilizer applied.

Y₀ = yield with no nutrient applied.

F = amount of nutrient applied;

The expressions are ratios on a mass basis and are therefore unit less in their standard form. N (Nitrogen) and P (phosphorous) can either be expressed on an elemental basis (most common in scientific literature) or on an oxide basis as P₂O₅ (most common within industry).

2.2.3. Organizations

Organizational performance is an important factor of sustainability and productivity of irrigation systems. Group-based irrigation systems imply an organization in charge of operation and maintenance activities. Small scale irrigation schemes, including their main water supply infrastructures, might be managed entirely by a WUA. The objective is greater user commitment, which can lead to more efficient use of the resources by helping to overcome many of the problems that public irrigation systems face, such as inequitable water distribution, corruption, inefficiency, drainage and poor operation and maintenance.

According to Blank *et al.* (2002), few among the institutional arrangements which facilitate collective action in small-scale irrigation systems, and which include the following:

- ✓ Users organization and their by-laws, and enforcement characteristics
- ✓ Stakeholders and their relationships in irrigation management (concerned government agencies, farmer's organizations and users).

Effective water control in irrigation management is a function of several factors including physical, technical, socioeconomic, organizational, political, cultural and complex institutional factors (Lawdermilk, 1981).

2.3. Types of Irrigation Schemes

In Ethiopia, modern irrigation system started since in 1960s for the purpose of producing industrial crops in Awash Valley. Makombe *et al.* (2011) noted that irrigation development is a key for sustainable and reliable agricultural development which leads to overall development in Ethiopia. Currently the Ethiopian government, under the growth and transformation plan, has given due attention to irrigation development projects, water center development, with priority given to small scale irrigation schemes. The government believes irrigation projects will help to better cope with climate variability and ensure food security.

Irrigation schemes are classified as small, medium or large-scale depending on the area irrigated, scale of operation and type of control or management. But the criteria used for classification may vary from country to country.

2.3.1. Small scale irrigation scheme

According to Lam (1996) the definition of “small scale irrigation systems” varies, depending on the way that specific country defines it. On another view, various criteria are used in referring to small scale irrigation and defining as the process of introducing effective water control technique to schemes with an independent water supply and a command area not exceeding 50ha, which are to be planned, developed and managed by farmers through the establishment of viable Water User Association (WUA) linked to existing social structure (FAO, 1998).

According to FAO (1998) small-scale irrigation can be highly cost effective when simple locally adapted techniques are used and that quick return can be expected as planning and design is implemented at local level with farmers directly contributing towards the construction. This also plays a vital role in poverty alleviation and improving the nutritional conditions of the rural poor who often do not receive the common benefits of economic growth.

According to Ethiopian irrigation scheme classification small-scale irrigation scheme (SSI) is defined as the area less than 200 ha; which are often community-based and traditional methods. Traditional irrigation has a long history in Ethiopia. During Derg regime period, very little attention was paid to small scale and traditional irrigation schemes constructed and managed by peasant farmers. The traditional small scale irrigation uses simple water diversions. It has been practical for decades in the high land where small farms could divert river, spring water seasonally for a limited dry season cropping.

SSI schemes are the responsibility of the Ministry of Agricultural and Rural Development (MoARD) and Regions (MoWR, 2002). Small-scale systems and technologies are attractive since they put the operation, maintenance and management of systems directly in the hands of the individual farmers, thus eliminating any need for centralized control or management (Jorma, 1999).

In general, according to McCornick *et al.* (2003) all small-scale systems may have advantages over large-scale systems. These advantages include that small-scale technology can be based on farmers existing knowledge; local technical, managerial and entrepreneurial skills can be used; migration or resettlement of labor is not usually

required; planning can be more flexible; social infrastructure requirements are reduced; and external input requirements are lower.

According to Yalew (2006) there is also limited supply of agricultural inputs and credit services on SSI schemes. There is no production plan, which severely affects the production market of SSI schemes. In general, the extension service became weak or eliminated whenever small scale irrigations are implemented.

2.3.2. Medium scale irrigation scheme

According to Ethiopian irrigation scheme classification medium scale irrigation scheme is covering 200 to 3,000ha, which is community based or publicly sponsored (Awulachew *et al.*, 2010b). It is the responsibility of Ministry of Water Resource (MoWR).

2.3.3. Large scale irrigation scheme

According to MoWR large scale is covering more than 3,000 hectares, which is typically commercially or publicly sponsored (Awulachew *et al.*, 2010b).The responsibility of MoWR.

Several important benefits accrue from medium and large-scale irrigation (LSI) that are relevant in the context of the Ethiopian irrigation sector, including: per hectare investment is less costly than the isolated small-scale schemes, particularly when compared with deep groundwater or small dams, and large-scale schemes can break the relationship between agricultural growth and rainfall.

However, critics of medium and large-scale irrigation argue that such schemes are to the benefit of commercial farms instead of smallholders. Additionally it has impacts of migration or resettlement of labor, planning is more complex, requires high initial investment cost and social infrastructural requirement increases.

2.4. Irrigation Scheme Performance Assessment

2.4.1. Importance of performance assessment

The evaluation of surface irrigation at field level is an important aspect of both management and design of the system. Field measurements are necessary to characterize the irrigation system in terms of its most important parameters, to identify problems in its function, and to develop alternative means for improving the system (FAO, 1989).

Hence, reliable measures of system performance are extremely important for improving irrigation policy making and management decisions. However, experience has shown that there are still considerable constraints and setbacks that hinder the introduction of small-scale irrigation.

According to Molden et al., (1989) 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.

2.4.2. Factors affecting the performance of irrigation schemes

According to Odi (1995), the factors that account for under performance of irrigation schemes include, among others:

- ✓ Poor system management and service provision,
- ✓ Poor understanding of farmer priorities and inadequate markets for produce,
- ✓ Lack of clear and sustainable water rights accorded to users, at on individual or group level,
- ✓ Lack of clear and recognized responsibilities and authority vested in the managing organizations,
- ✓ Lack of transparent accountability; and supporting incentives for the managing entities.

2.4.3. Performance assessment methods

The type of performance measures selected depends on the purpose of the performance activity. Generally there are four potential kinds of performance gaps that can be occur with irrigation systems (Douglas and Juan, 1999).

The first is a technological performance gap; this occurs when the infrastructure of an irrigation system lacks the capacity to deliver a given hydraulic performance standard. The normal solution to technology performance gap is to change the type, design or condition of physical infrastructure.

The second arises due to management gaps; arise due to the difference between the procedures to be implemented and actually implemented; i.e. how people adjust gates,

maintain canals and report information. This can be called a gap in implementation performance. A problem of this kind generally requires changes in procedures, supervisions or training.

The third kind of performance gap is a difference between management targets and actual achievements. This can be called a gap in achievement. Such problems are generally addressed either by changing the objective or increasing the capacity of management to achieve them (increasing the resource available or reforming organizations).

The fourth one is impacts of management, the difference between what people think should be the ultimate effects of irrigation and what actually results. These are gaps in impact performance and include such measures as agricultural and economic profitability of irrigated agriculture, productivity per unit of water, poverty alleviation and environmental problems such as water logging and salinity. If management procedures are being followed and targets are being achieved, but ultimate impacts are not as intended, then the problem is not that the managing organization has performed badly, since these effects are generally beyond its direct control. The problem is more a problem of policy than management.

Most authors propose to use different indicators and different methodologies or tools to measure the same indicators (Bos *et al.*, 1994). But this causes much confusion in evaluation. To avoid this, studies recently categorized indicators into two groups to evaluate irrigation systems; process /internal/ performance and comparative /external/ performance assessment methods.

2.4.3.1. Process performance assessment

Process measures refer to the processes ***internal to the system*** that lead to the ultimate output, where as output measures describe the quality and quantity of the outputs where they become available to the next higher system (Molden *et al.*, 1998). According to Molden *et al.* (1998) much of the work to date in irrigation performance assessment has been focused on internal processes of irrigation systems. Many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated; and cropping patterns.

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

Common indicators defined in the literature include:

- ✓ Conveyance, distribution, field and application, and project efficiencies;
- ✓ Reliability and dependability of water distribution;
- ✓ Equity or spatial uniformity of water distribution; and
- ✓ Adequacy and timeliness of irrigation delivery

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

2.4.3.2. Comparative performance assessment

In addition to using process indicators, IWMI suggests using a minimum set of comparative indicators to assess hydrological, agronomic, economic, financial, and environmental performances of irrigation systems. The aim of applying comparative indicators is to evaluate outputs and impacts of irrigation management practices, interventions across different systems and system levels; as well as to compare various irrigation seasons and technologies with one another.

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).

2.4.4. Performance indicators

Indicators are used to measure performance. An indicator describes the level of actual achievements in respect of objectives of irrigation. It is useful to consider an irrigation

system in the context of nested systems to describe different types and uses of performance indicators (Small and Svendsen, 1992). An irrigation system is nested within an irrigated agricultural system, which in turn can be considered part of an agricultural economic system. For each of the system, process, output, and impact measures can be considered.

An irrigation system, consisting of a water delivery and a water use sub-systems, 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 & Sampath, 1995).

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

The number of indicators should use depends on the level of detail with which one needs to quantify (e.g., research, management, information to the public) performance and on the number of disciplines with which one needs to look at irrigation and drainage (water balance, economics, environment, management). A true performance indicator includes both an actual value and planned value that enables the assessment of the amount of deviation. It further should contain information that allows the manager to determine if the deviation is acceptable.

Some of the desirable attributes of performance indicators suggested by Bos (1997) are:

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

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

Reference to a target value: This is, of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator. These target values and their margin

of deviation should be related to the level of technology and management (Bos et al., 1991).

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

Ease of use and cost effectiveness: Particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment, and commitment of human resources, should be well within the agency's resources.

2.4.5. Features of comparative performance indicators

The application of comparative performance indicators will provide system managers, researchers, and policy makers with information on differences in performance and, as a consequence, enable them to identify gaps in irrigation management policies. According to Molden et al. (1998); generally comparative performance indicators are:

- ✓ Reveal general notions about the relative health of the irrigation system, yet they are not too data-intensive to discourage widespread and regular application.
- ✓ The indicators are based on a relative comparison of absolute values, rather than being referenced to standards or targets.
- ✓ The indicators relate to phenomena that are common to irrigation and irrigated agricultural systems.
- ✓ Indicators potentially have several purposes. It will allow for comparison between countries and regions, between different infrastructure and management types, and between different environments, and for assessment over time of the trend in performance of a specific project.
- ✓ They will allow an initial screening of systems that perform well in different environments, and those that do not.
- ✓ They will allow for both assessing impact of interventions and managers to assess performance against strategic, long term objectives.
- ✓ The set of indicators is small, yet reveals sufficient information about the output of the system.
- ✓ Data collection procedures are not too complicated or expensive.

- ✓ The indicators relate to outputs and are bulk measures of irrigation and irrigated agricultural systems, and thus provide limited information about internal processes.

A relative comparison of values at least allows us to examine how well one system is performing in relation to others. And, if we have enough samples, this approach may ultimately allow us to develop standards and targets. The main audience for these external indicators comprises policy makers and managers making long-term and strategic decisions, and researchers who are searching for relative differences between irrigation systems while the main audience for internal indicators comprises irrigation system managers interested in day-to-day operations where ratios of actual to target values may be quite meaningful.

2.4.6. Selected performance indicators

Moreover IWMI developed many indicators in each group of process and comparative performance indicators. However for this study the following indicators have been selected:

2.4.6.1. Water delivery indicators

Determined based on irrigation and water supply measurements being related to demands. This includes conveyance efficiency, Relative water supply (RWS) and Relative irrigation supply (RIS).

Conveyance efficiency

Effective conveyance ratio (CE) represents the capability of a canal reached to carry water with loss, while the conveyance loss (L) is the amount of losses occurred in the specified length of canal reaches

Conveyance efficiency is defined as 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 system or simply it is the ratio of outflow rate to inflow rate of a system. It is one of closely related and commonly used output measures of performance that focus on the physical efficiency of water conveyance by the irrigation system (Bos, 1997). Bos *et al.* (1994) 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.

Losses of irrigation water occur during convey of water from the head of a canal to the farm plot. In open canals, such losses take place primarily due to evaporation and seepage. About 10 to 15% of the water admitted in to a canal can get lost in this way (Mazumder, 1983).

Relative water supply (RWS)

This is the ratio of total annual water supplied (irrigation plus rainfall) to the annual crop water demand (Levine, 1982). It signifies whether the water supply is in short or in excess of demand.

Relative irrigation supply (RIS)

This is the ratio of annual irrigation supply (which excludes rainfall) 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 or abundance in relation to irrigation demand. It is the inverse of irrigation efficiency presented by (Bos, 1997).

Both RWS and 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 1, it indicates water supply was beyond the water demand; if it is less than 1, the water supply was below the water demand. While if it is equal to 1, the supplied amount of water was sufficient to demand, i.e. neither surplus nor deficit. Most of the time it is better to have a RIS near 1 than a higher value.

However, care must be taken in the interpretation of results; an irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate appropriate use of available water; a lower RWS would actually be less desirable. Likewise, the value 0.8 may not represent a

problem; rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water.

Molden *et al.* (1998) investigated varied values of RWS indicators between 0.8 and 4, from 18 different irrigation schemes in the world. When irrigation tightly fills the gap of water requirements after they are met by rain, RIS is near unity. Similarly Molden *et al.* (1998) reported a wide variation in RIS values among the systems studied, from 0.41 to 4.81.

2.4.6.2. On-farm Water management indicators

1. Agricultural out- put indicators (land and water productivity)

It includes evaluation of Output per unit irrigated cropped area (\$/ha), Output per unit command area (\$/ha), Output per unit irrigation water supply (\$/m³), Output per unit irrigation water delivered (\$/m³) and Output per unit water consumed (\$/m³). These “external” indicators provide the basis for comparison of irrigated agriculture performance. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important (Molden *et al.*, 1998).

The output per unit water consumed is the volume of process consumption, in this case evapotranspiration. It is important to distinguish this from another important water accounting indicator output per unit total consumption, which includes water depletion from the hydrological cycle through process of consumption (ET), other evaporative losses (from fallow land, free water surface, weeds , trees), flows to sinks (saline groundwater and seas), and through pollution.

We are interested in the measurement of production from irrigated agriculture that can be used to compare across systems. It could be argue that the indicator should be net value added rather than gross. There are two reasons to work with the gross figure. First, it is far easier to measure many of the deductions that must be made to get from gross to net value added are susceptible to distortions (subsidies and taxes on inputs, credit, and irrigation services, for example) or otherwise very difficult to measure (appropriate prices for family labor, and the opportunity cost of land and water).

Second, we note that the most common indicator of agricultural performance (yield per unit land, or more commonly just ‘yield’) is itself a gross indicator, unqualified by

indications of input levels, soil type, or even variety. Despite this simplicity, yield serves many agriculturists as a fundamental indicator of performance.

2. Fertilizer utilization efficiency (FUE)

It is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil- and plant-water management. An excellent review of nutrient utilization efficiency measurements and calculations was written by (Dobermann, 2007). Amongst a number of indicators two of them were selected for performance evaluation i.e. partial factor of productivity (PFP) and agronomic efficiency (AE).

Partial factor of productivity (PFP)

It is a simple production efficiency expression, calculated in units of crop yield per unit of nutrient applied. It is easily calculated for any farm that keeps records of inputs and yields. However, partial factor of productivity values vary among crops in different cropping systems, because crops differ in their nutrient and water needs. A comparison between crops and rotations is particularly difficult if it is based on fresh matter yields, since these differ greatly depending on crop moisture contents (e.g. potato vs. cereals).

Agronomic efficiency (AE)

It is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return. The calculation of AE requires knowledge of yield without fertilizer input /zero fertilizer input/. However, if it is calculated using data from annual trials rather than long-term trials, FUE of the applied fertilizer is often underestimated because of residual effects of the application on future crops. Estimating long-term contribution of fertilizer to crop yield requires long-term trials.

Very high AE is measured when soil fertility is well below critical levels and rapidly decline as soil fertility increases. Sustainability is associated with the intermediate AE value observed when rates applied are close to removal, and soil fertility levels are maintained near the critical level.

Table 2.2: PFP and AE levels for cereal crops (primarily maize, rice, and wheat)

Measure	Typical level		Interpretation
	N	P	
Partial factor productivity (kg grain (kg nutrient) ⁻¹)	40-90	100-250	Lower levels suggest less responsive soils or over application of nutrients while higher levels suggest that nutrient supply is likely limiting productivity.
Agronomic efficiency* (kg grain (kg nutrient) ⁻¹)	15-30	15-40	Lower levels suggest changes in management could increase crop response or reduce input costs.

* Based on first year response.

The specified ranges will be applicable when recommended management practices are employed and where soil available N and P levels are currently within a recommended range. The ranges were selected by Drechsel *et al.* (2015), based on reported values in the published literature and best judgment on what typical levels are when practices recommended for the region are being followed. These values should be replaced with levels based on local research and experience whenever possible.

The FUE terms in table 2.2 could be estimated at scales ranging from global to small areas within individual fields. Scalability is a desired attribute for performance indicators, because it makes linkages clearer between local management practices and larger-scale impacts. However, the certainty and reliability of the estimation for specific sites decrease as the scale increases. In any case, these estimates depend on the quality of the data used in calculations.

Table 2.3: PFP for N applied to cereals for world regions and associated average fertilizer N rates and crop yields.

Region	N rate (kg ha ⁻¹)	Cereal yield (t ha ⁻¹)	Grain N* (kg ha ⁻¹)	PFP (kg grain (kg N) ⁻¹)
Sub-Saharan Africa	9	1.1	17	122
Eastern Europe, Central Asia	25	2.1	32	84
Oceania	48	1.9	29	40
Latin America	55	2.9	44	53
South Asia	58	2.4	36	41
Southeast Asia	65	3.2	48	49
West Asia, North Africa	68	2.3	35	34
Northeast Asia (Japan, S. Korea)	89	6.1	92	69
North America	112	5.1	77	46
Western Europe	113	5.5	83	49
East Asia (China, Vietnam, Korea DPR)	155	4.8	72	31
World	70	3.1	47	44

*Assuming 15 kg N t⁻¹ of cereal grain. Fertilizer N rate and cereal yield for years 1999-2002/03 reported by Dobermann and Cassman, 2005.

Furthermore Ladha *et al.* (2005) carried out an extensive review of 93 published studies; where FUE was measured in research plots for various world regions.

Table 2.4: PFP and AE values for N for maize, wheat, and rice

Crop or region	Av. rate of fertilizer use (kg ha ⁻¹)	PFP (kg ha ⁻¹)	AE (kg ha ⁻¹)
Maize	123	72	24
Wheat	112	45	18
Rice	115	62	22
Africa	139	39	14
Europe	100	50	21
America	111	50	20
Asia	115	54	22
Average/totals		52	55

Whether trials are in farmer fields or on experiment stations, high-yield cereal systems tend to have higher AE than systems at lower yield levels. This should not be surprising since the higher nutrient requirements of crops at high yield levels are likely to exceed the nutrient supplying ability of soils without the application of fertilizers to a greater extent than at lower yield levels. This increases the difference between the yield of the crop with the application of fertilizers and the yield of the crop without the application of fertilizers.

2.4.6.3. Physical performance indicators

It is a useful indicator for assessing the sustainability of irrigated agriculture. Ascertaining the likely sustainability of a system over time requires determining a variation with respect to time (season, year, etc) of key indicators, tracing the secular trends and understanding the processes causing these trends (Rao, 1993). Assessment of time dependent variation of adverse effects like water logging, salinity, flooding etc are important for monitoring a system's physical sustainability. Sustainability has many dimensions and they will probably be more country specific and project specific. For this study irrigation ratio and sustainability of irrigated area indicators were selected.

2.4.6.4. Financial indicators

This study was only focus on gross return on investment; the indicator considers the production value and the total cost of infrastructure for each scheme. Policy makers are keenly interested in the returns to investments made. Similarly, researchers would like to be able to recommend systems that yield acceptable returns within a given environment. Large irrigation investments are made in irrigation infrastructure, thus returns compared to investment in infrastructure are presented. We focus on water delivery infrastructure to be able to analyze.

According to Molden *et al.* (1998) infrastructure related to river diversions, storage, and drainage is not included here, the desire is to compare the delivery systems because the diversion weir and storage works may also serve other non-irrigation purposes. The cost of the distribution system can either be estimated from original costs, or estimated by using present costs of similar types of infrastructure development.

The values of gross return on investment of 18 different irrigation schemes in the world shows a wide variation between 7 to 75% (Molden *et al.*, 1998). Rice based irrigation systems with less abundant water give a low return on investment (6 to 30%), while private pump irrigation systems provide the highest rate of return on investment (75%).

2.4.6.5. Organizational indicators

The roles of water users associations;

Attention is nowadays being focused on how to achieve this commitment, and to what extent WUAs can be assisted to form and to manage their own affairs (FAO, 1996). Many conflicts occur due to the problem of water theft or unauthorized canal breaching in the

scheme. There is a conflict resolution mechanism and most WUAs develop their by-laws which is a system rules for controlling the conflict within the scheme. The WUAs committees have long existed to manage SSI schemes. They are generally well organized and effectively operated by farmers. The associations handle construction, allocation, operation and maintenance functions with government technical and material support (MoWR, 2002).

Irrigation schemes that constructed after 1975 were failed because the irrigation systems denied operational autonomy, top-down approach. Under the centralized governmental management, operation and maintenance activities were also usually inadequately performed (MoWR, 2002). Since 1991 farmers or communities are forming their own organizational set ups (WUAs) for own and autonomous management of irrigation schemes with support from government and NGOs (FAO, 1998; MoWR, 2002). However, most of the time WUA's bylaws and administrative issues were not legally entitled and couldn't enforced in end, unless the communities ruled by own cultural rules.

Recently the government of Ethiopia declared a proclamation No. 841/2014 on the formulation and administration of Irrigation Water users Associations /IWUAs/, (Federal Negarit Gazette, 2014).

The main objectives for the formulation of this proclamation are;

1. To put in place compatible legal framework for farmers' management of irrigation and drainage systems.
2. To establish a system for the formation of self-regulating non-profit oriented irrigation water user's associations that act in the public interest to provide irrigation and drainage services in rural areas.
3. To establish a legal basis for the transfer of irrigation and drainage systems constructed by government fund to associations to regulate supply of services between associations and service providers to achieve improved management of water resources.

Furthermore; Jari SSI scheme's bylaw was declared as; ' Internal bylaw of Jari-Tehuledere Irrigation Users No. 001/2004E.C'; it has 22 pages including cover page. It comprises detailed internal rules, regulations, responsibilities of water committees, amounts of fees for water and maintenance, the penalties on illegal users, institutional and stakeholder responsibilities.

Some major rules and regulations in Jari SSI scheme:

- Not allowed to plough near to canals, must far 1m from left and right edge. If who is found guilty, will be punished 50ETB for the first time and 100ETB for second time.
- If any user who abstracts water from main turn out of his turn, he will pay 100, 200 and 500ETB for the 1st, 2nd and 3rd times respectively.
- If any user who abstracts water from the water group turn out of his turn, he will pay 50, 100, and 300ETB for the 1st, 2nd and 3rd times respectively.
- A farmer who is found guilty of breaching canals and diverting water where there are no turn outs will pay 50ETB for the first time and 100ETB for the second time. Additionally if he damaged the structure, he will pay for maintenance costs estimated by experts.
- If the executive committee, water user team 'ketena' leader and water group leader are not carried out their responsibly and if it is assured by the control and monitoring committee, they will be punished 50 and 100ETB for the first and second time respectively; after they will be removed from their position and responsibility.

Additionally the SSI schemes suffer by multifaceted problems including management and organizational problems, lack of access to credit and input and marketing facilities. The scheme technically the structures deteriorated before their service life and some of them are left unused. With this issue Dejen and Yilma (2001) argue that inefficient and under utilization of available capacity of the schemes in Ethiopia arise from giving more emphasis to technical aspects and less emphasis to the managerial and institutional issues.

It can be evaluated quantitatively and qualitatively in the form of;

- ✓ Organizational structure and functions of WUAs
- ✓ WUA's by-laws and enforcement; conflict resolution mechanisms
- ✓ Fee collection (membership, water fee, etc...),
- ✓ Beneficiary participation in operation and maintenance
- ✓ Extension service and marketing
- ✓ Water allocation and distribution

2.5. Concluding Remark

In general irrigation systems are composed from several components that interact with one another; i.e. irrigation scheme, on-farm water management and organizations. For better achievements and sustainability of the system there should be a close association between the components at different levels. Land productivity, water productivity, selection of crops, irrigation intensity, on farm management practices, technology and input utilization /fertilizers, chemicals/ and organizational arrangements and functionality are highly affects the productivity and sustainability of the irrigation schemes. Due to poor linkages of the above factors recently many small scale irrigation schemes are under utilization and structurally under failure. As result to characterize the level of utilization of the given irrigation scheme field measurements and performance evaluation works are very relevant.

Process indicators help system managers to monitor the quality of water delivery services. While comparative indicators used to assess hydrological, agronomic, financial and environmental performances of irrigation systems and to evaluate outputs and impacts of irrigation management practices across systems. Water delivery, on farm water management, physical, financial and organizational performances are highly contributed for the productivity of the given irrigation schemes. Water delivery indicators include conveyance efficiency, relative water supply indicators and relative irrigation supply indicators. Properly conveying of water from diversion weir to farm inlet is the main factor for the productivity of the scheme. The output per unit irrigated and command area, water productivity per unit diverted and delivered amounts are also affects the value of total output production levels. Additionally the level of organizational setups and farmers participation in scheme management and maintenance works has a positive contribution for the productivity of the irrigation schemes. As a summary the selected minimum performance indicators which have employed for this study were reviewed. Thus based on the selected performance indicators and their applications the selected small scale irrigation schemes performance levels, achievements and gaps have been identified and benchmarked in the next study sections.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Tehuledere district

The study area Tehuledere district is found in Eastern Amhara Regional state under South Wollo administrative zone. It is located 430 km far from Addis Abeba in the Northeast direction and geographically lies at 11°10'30''- 11°29'25'' N latitude and 39°35'30''- 39°45'45'' E longitude. According to CSA (2007) report the district has a total population of 117,877; of whom 59,300 are men and 58,577 are women. It covers an area of 405.37 square kilometers and contain notable landmarks include the monasteries of Debre Egziabeher and Hayk Istifanos.

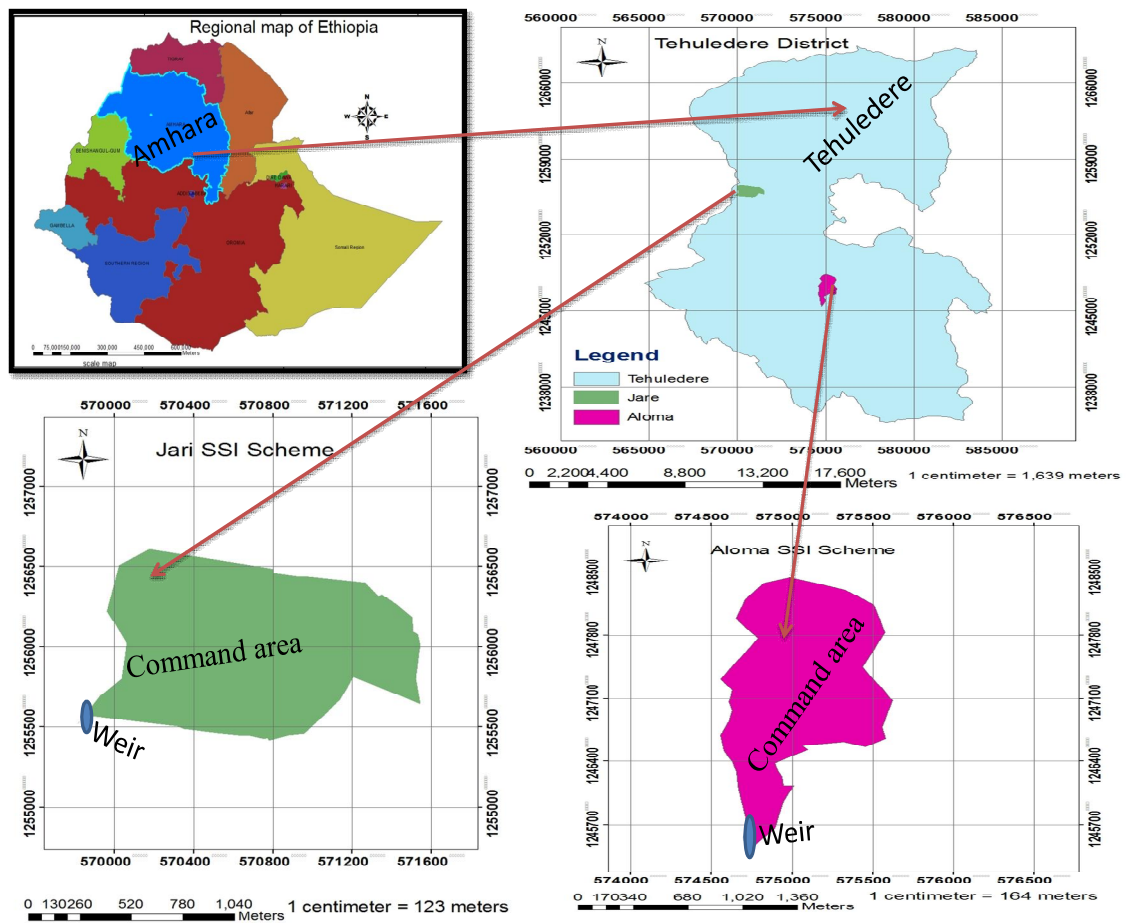


Figure 3.1: Location map of the study areas

The hydrology of the area includes Lake Ardibo and Logo Hayk and the drainage system flows to Mile River. Mile River separates Tehuledere from Ambasel to the Northwest direction. The district has altitudinal ranges of 500-2,700m a.s.l and contains diversified agro-ecological zones with the range from ‘Dega’¹ to ‘Kola’² (MOA, 2000). The district categorized in sub humid tropical climate of bimodal rainfall pattern. However the space-time distribution of rainfall is highly variable. For this research purpose, Jari and Aloma small scale irrigation schemes were selected.

3.1.2. Jari small scale irrigation scheme

Jari small scale irrigation scheme is a check basin type of diversion system; the head work has no any water flow control gates. It is found in Tehuledere district, in the right side direction from the main road Woldia to Dessie. It is 10km far from Hayk Town in the way to Woldia direction. The area is geographically located at 11⁰ 21’22’’-11⁰ 22’0’’ N latitude and 39⁰38’23’’- 39⁰ 39’23’’ E longitude and has an average altitude of 1697m a.s.l.

The area is categorized under sub-moist cool ‘weinadega’ agro-ecological zone. The mean average sunshine hour reaches to 6.7 hrs. The rainfall distribution is a bimodal type, contains ‘Kiremet’³ and ‘Belg’⁴ season, but the Belg season rainfall has not been as such predictable in amount and time. The area receives a total annual average rainfall of 1065.85mm; from this 817.4 mm is effective rainfall. The mean average ETo, minimum and maximum temperature of the area is 4.38 mm/day, 13.22⁰C and 27.43⁰C, respectively.

The irrigation scheme has total household beneficiaries of 537 (446 Male and 91 Female). The initial total command (nominal) area was 168 ha but currently it is declined to 146 ha. The slope of the area ranges up to 50% in the downhill of the watershed and 2% in lower part of the scheme. The primary soil type in the study area is the tropical plateau black clay soil with some distribution of brown soil and new alluvial, and the soil is sticky and hardened with poor content of organic matter and nutrients, lower capacity of holding moisture, soil and fertilizer (ORDA, 2005).

¹ Cold area which has altitude ranges from 2,500-3,500m and annual rainfall of >1,000mm.

² Sub-moist warm area which has altitude ranges from 500-1,500m and annual rainfall of 900-1000mm.

³ A long rainy /main/ season from June to October

⁴ A short rainy season from February to April

Jari Small Scale Irrigation Scheme's, main water source is Mile River and some additional minimum flow comes from the surrounding areas, bottom hill of the upper watershed, (Kezikaze River, Tirngo, Wulko and Muk Wuha springs). The irrigation system was constructed for demonstration purpose, so as to serve as a sample model of demonstration for a wide range of the agricultural area, by the regional government; *'Agricultural Comprehensive Development and Programming in Jari-Ful Wuha Watershed in Upper Mile River'*.

Generally, the scheme has an advanced design and structural systems of night storage and rain water harvesting ponds connected with the irrigation canal networks, but currently it is not as such satisfactory in services. The implementation of water harvesting ponds with irrigation system in the watershed was initiated by South-South Cooperation agreement signed among the Ethiopian government, FAO and the Chinese government. Prior to the implementation of the project, feasibility studies supported by FAO were carried out in the watershed by Chinese and Ethiopian experts in 2002 and 2005. The design of the water harvesting ponds with irrigation scheme was made by Chinese experts.

The Amhara National Regional Government took a contractual agreement with Organization for Rehabilitation and Development in Amhara (ORDA). In the meantime, ORDA received a construction responsibility to implement the irrigation project in the watershed according to predetermined design and the construction was completed in 2005. The total investment budget for the construction of engineering, biological and other measures was 7,192,611ETH birr; the engineering cost covers 84.74% of the total (ORDA, 2005). Currently the operation and management of the scheme has been lead by WUAs.

3.1.3. Aloma small scale irrigation scheme

Aloma small irrigation scheme is a diversion weir system type, it is gated but it has not been functional. The scheme is found in Tehuledere district and geographically the area lies; 11⁰15'58''-11⁰17'9'' N latitude and 39⁰40'41'' - 39⁰41'35'' E longitudes. It is far 8 km from Hayk town; found in the left side direction from the main road of Woldia to Dessie.

The average altitude of the area reaches to 2033m a.s.l. The area is categorized under ‘Erteb Weinadega’⁵ agro-ecological zone. It has a bimodal rainfall pattern; ‘Kiremet’ season from June to October and ‘Belg’ from February to May. The area has a total annual rainfall of 1202 mm and 797.6 mm effective rain fall. The mean average daily ETo, sunshine hours, minimum and maximum temperature are 4.34mm/day, 6.57hrs, 10.40°C and 26.27°C, respectively.

It has a total designed command area of 210ha, but currently the irrigable area is only 115ha. The irrigation beneficiaries are 232 (195 Male and 37 Female). The irrigation area is categorized under gentle slope topology; has an average slope of 2-15%. Specifically the secondary canal alignment is along the slope. The dominant soil is clay soil.

Aloma Small Scale Irrigation Scheme’s water source is Gelana River; which drain to Mile River. It was constructed in 2012 by Bureau of water Resource (BoWR), a budget source from Food Security Program (FSP) with a total investment cost of 7,500,000 ETB. The operation and management has been controlled by WUAs.

3.2. Data Collection and Analysis

3.2.1. Data collection methods

This research was carried out starting from March to June; 2015 of the irrigation season. In this study quantitative and qualitative research approach; primary and secondary data have been gathered and engaged for the study purpose. For field data collection and measurement purposes; Current Meter, Double ring Infiltration-Meter, Auger, Tape Meter, Cutthroat Flumes, Garmin GPS and Sensitive Balance were used during the study period.

⁵ Moist Cool area which has altitude ranges from 1,500-2,500m and annual rainfall of > 1,000mm.

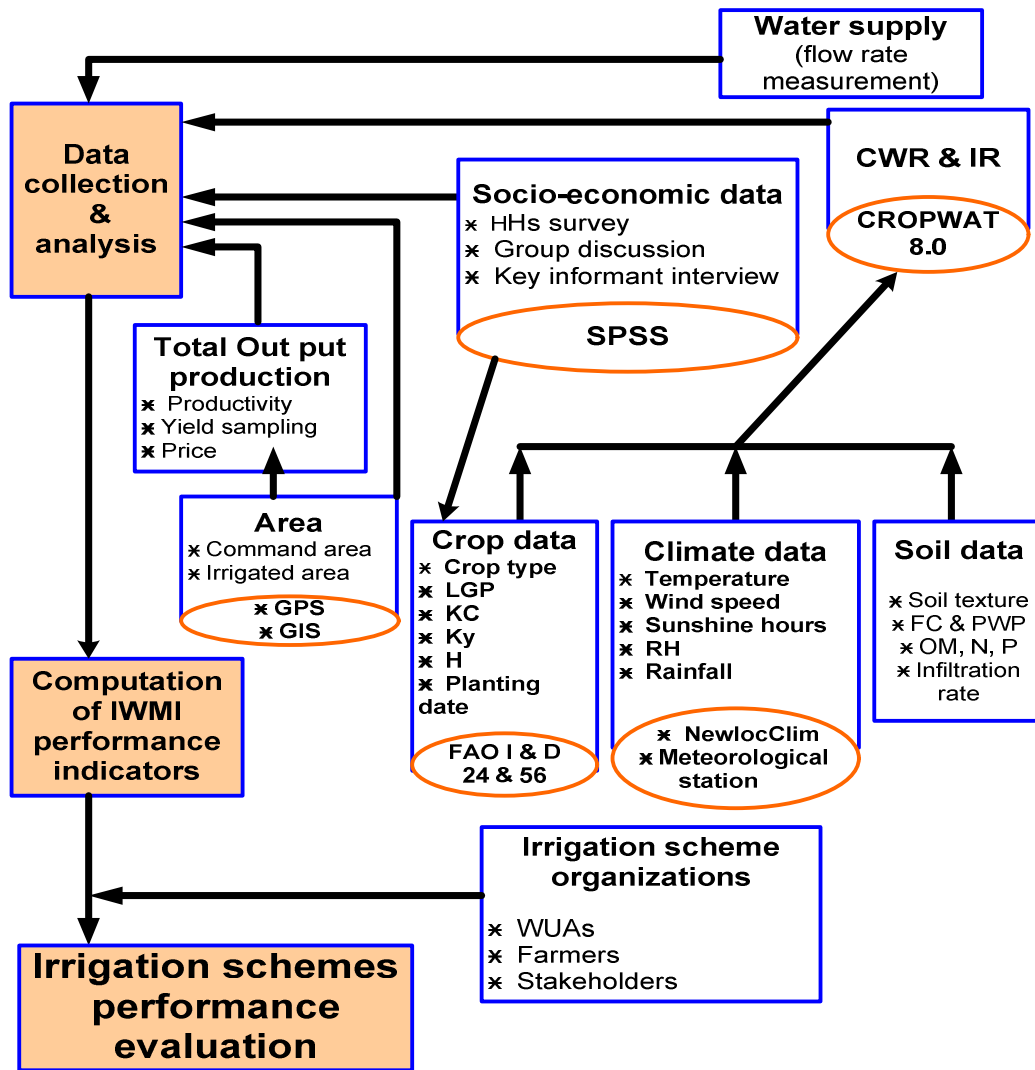


Figure 3.2: Flow chart of methodology adopted in the present study

3.2.1.1. Primary data collection

Various types of primary data have been collected through formal and informal survey approaches. Field surveys, house hold surveys, key informant interviews with respective stakeholders and group discussions have been deeply practiced for cross comparison and wellbeing of information gathering and analysis.

A comprehensive field survey has been carried out starting from March to June 2015. Soil samples were collected for the determination different soil parameters and soil infiltration rate test was taken for both sites. Additionally GPS data were also recorded.

1. Yield sampling

For the computation of fertilizer utilization efficiency (FUE) performances, in the irrigation schemes, yield samples from farmers who have used fertilizer and not used were taken from main crops at both irrigation schemes.

Table 3.1: Yield samples of main crops at both irrigation schemes

Jari SSI scheme			Aloma SSI scheme		
Crops	Number of sampled farmers		Crops	Number of sampled farmers	
	Used fertilizer	Not used		Used fertilizer	Not used
Teff	4	4	Teff	3	3
			Wheat	6	6
			Potato	3	3

2. Soil Sampling

Composite soil samples at 30cm and 60cm depths have been collected at each stratum for the determination of soil physical properties; soil texture, Field capacity (FC) and Permanent Wilting Point (PWP), and chemical properties of the macro nutrients like Nitrogen (N) and Phosphorus (P); the values have been computed through laboratory working procedures.

For the determination of soil textural class two composite soil samples at the specified depths were taken at each stratum (head, middle and tail). Soil particle size composition of each particle was calculated in laboratory. Based on the percentage of composition, the soil textural class was determined by USDA soil textural triangle method (Bouyoucos, 1951), see appendix figure 1. And also two composite soil samples were taken for the determination of soil nutrient contents (N and P) and the value was computed in laboratory.

For the determination of total available water (TAW) amount in the soil; field capacity (FC) and Permanent wilting point (PWP) of the soil was determined by taking two composite soil samples from each stratum. The analysis was carried out through pressure plate apparatus in the laboratory.

The total available soil moisture for the plant is between FC and PWP. The magnitude of the total available moisture is a function of soil texture and structure and indicates the capacity of the soil to have water extracted by the plant. TAW is the total amount of water a crop can extract from its root zone. Before a wilting point reached a plant is already

suffering from water stress. Readily available water (RAW) uses the fraction (P) of the total saturation that can be safely removed before stress occurs. Based on soil parameters of textural class, FC, PWP could specify the value of depletion fraction (P) from FAO recommendations.

The soil infiltration rates of the two schemes were characterized by using double ring infiltro-meter apparatus. Infiltration is the process of entry of water downwards from the air medium to soil, or from soil surface into the soil medium. This phenomenon has a greater practical importance in irrigation and rain-fed farming systems. Infiltration characteristic of the soil is one of the dominant variables influencing irrigation application.

When sufficient water is applied and maintained at atmospheric pressure, the flux (i.e. the volume of water passing through a unit cross sectional area per unit time) flowing into the soil profile is termed as infiltration rate. Infiltration rate is very rapid at the start of water application, but it decreases rapidly with the advance of time and eventually approaches to constant value. The nearly constant infiltration rate that reaches after some lapsed time from start of irrigation is termed as the *basic infiltration rate* (Appendix figure 3 & 4). This value, *basic infiltration rate*, was used as an input data for CROPWAT 8.0 model, for the computation of crop water and irrigation requirements.

3. Water flow rate measurement

Water flow rate measurement is a relevant data for irrigation scheme performance evaluation activities, computation of conveyance efficiency and losses. There are different methods to measure the flow of water in the rivers/canals. For this study Current Meter and Cutthroat Flume water flow rate measurement equipments were used.

Frequent flow measurements have been taken starting from intake to referenced point of main and secondary canals; through using Current Meter.

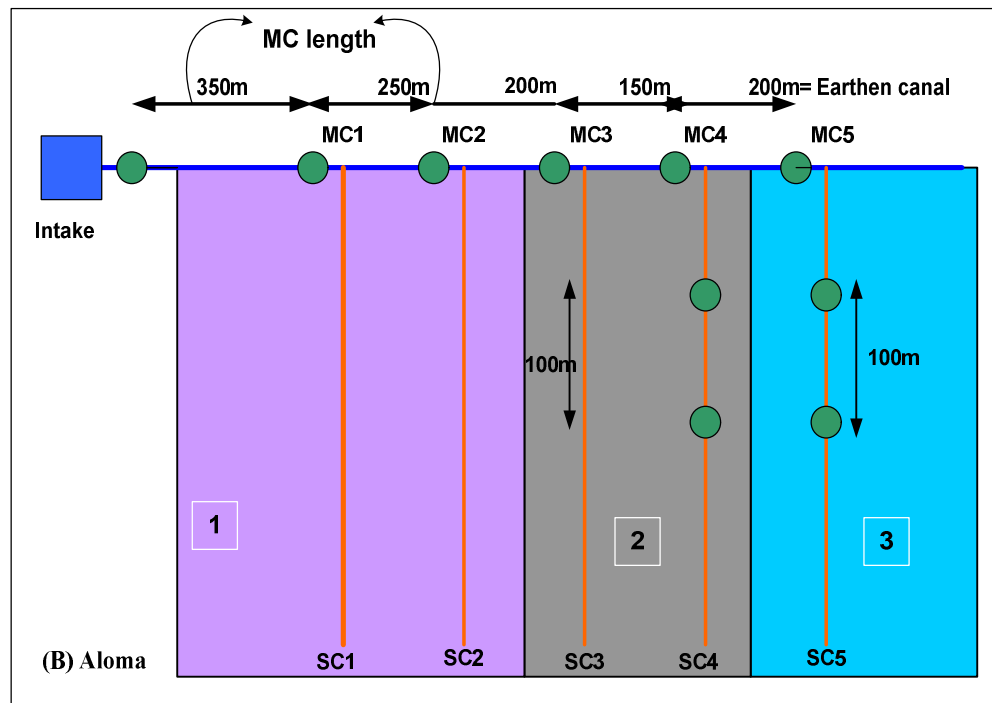
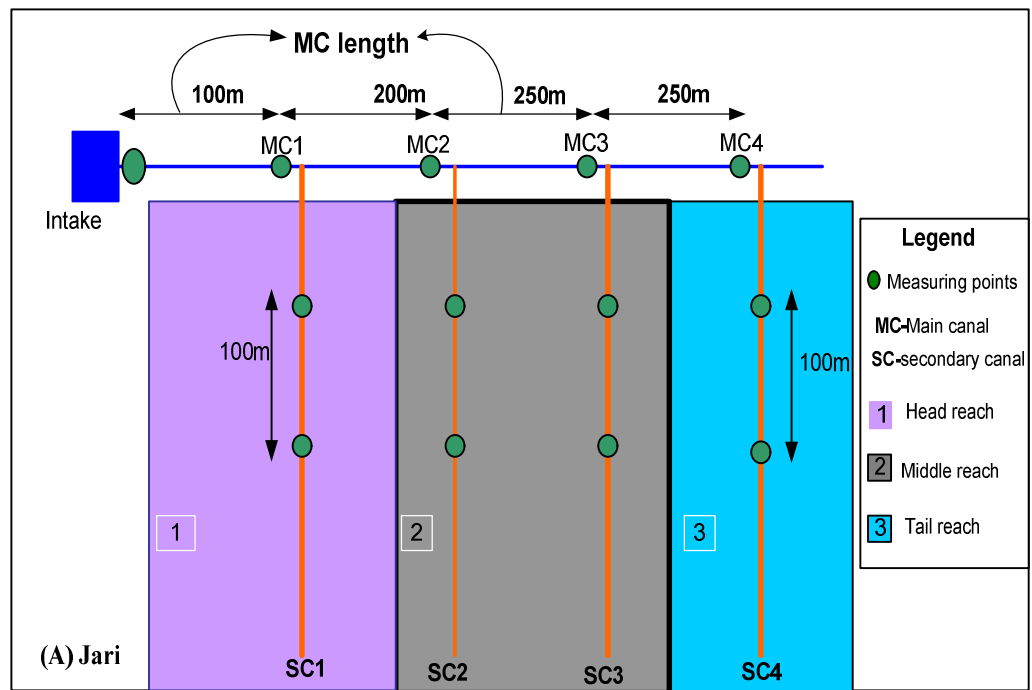


Figure 3.3: Layouts for water flow rate measurement points (not scaled)

Through Current Meter; at straight and regular reach of intake, main canals and secondary canals; flow rate measurements were taken in weekly bases to capture temporal and spatial fluctuates of irrigation water flows along the scheme; for three months, starting from March to June 2015 irrigation season.

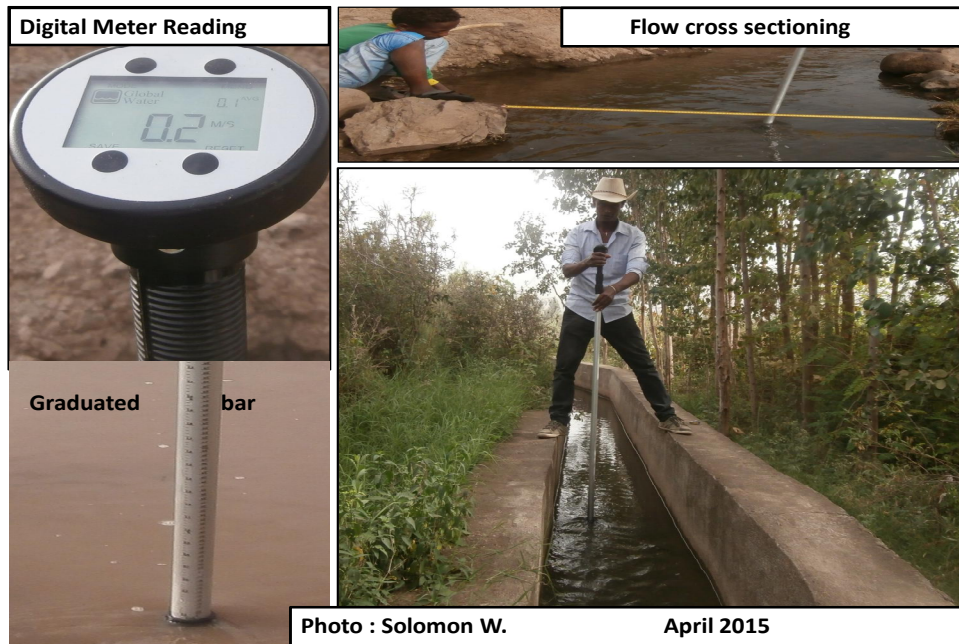


Figure 3.4: Water flow rate measurement trough current meter

From the main canal (head of major secondary canals) 4 for Jari and 5 for Aloma measuring points, were bench marked to capture the amount of inflow before entering to the secondary canals and out flow; used to compute lost amounts relative to the diverted amounts. The main canal and secondary canal of Jari irrigation scheme is constructed in lined masonry.

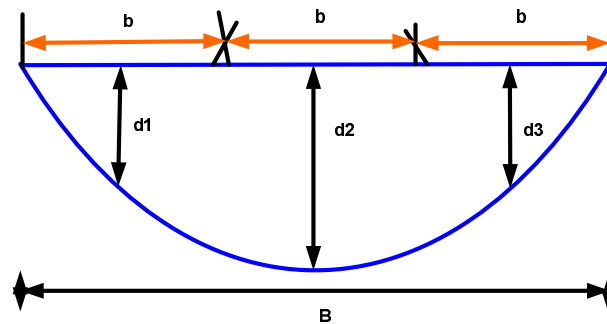


Figure 3.5: Canal flow cross section

Aloma irrigation scheme's primary canal is constructed in lined masonry and only 200m is earthen canal type; whereas the secondary canal is lined but it is cracked and fractured, and it has been out of function.

The cross sectional structure of Jari and Aloma SSI schemes is rectangular. The discharge amount would be equal to the product of the average velocity (V_a) and the area of the cross-section (A). The wetted width of the canal was divided into three equal cross sections (at left edge, center and right edge) and the flow depth was measured at each division. The average flow velocity was measured at a depth of $(0.6*d)$ from the water surfaces at each vertical; where 'd' is the respective depths of each division.

The discharge (q), in each sub section of the canal could be determined by applying the area of the sub section by the average flow velocity in that section. The total discharge would be the summation of individual discharges in the specified cross section.

$$q = b * \left(\frac{d1 + d2}{2}\right) * \left(\frac{V1 + v2}{2}\right) \dots \dots \dots [3.1]$$

$$Q = \sum_{n=1}^n q \dots \dots \dots [3.2]$$

Where;

$d1, d2, d3$ = flow depth at each cross section (m)

B = bottom width (m)

b = wetted width of the cross section (m)

q = individual flow rate at each cross section (m^3/s)

V = velocity (m/s)

Two measuring points have been fixed in 100m length at secondary canals, to capture the amount of losses and to compute the conveyance efficiencies. The computation was carried out in similar procedure like main canal. For the case of Jari SSI scheme flow rate was measured at Secondary canals of (1, 2, 3 and 4) at two locations at each canal. While in Aloma SSI scheme flow rates were measured at two secondary canals of 4 and 5 in 100m length. Unlike, Jari SSI scheme, Aloma SSI scheme's main canal inflow is divided into two secondary canals; due to small cross section and maintenance problems.

To determine the flow rate at farm inlets measurements were taken by Cutthroat Flumes from sampled farmers. Totally nine farmer plots were selected purposively from farmers that has been selected for questionnaire survey at each canal reaches (head, middle and tail) at both schemes. The Cutthroat Flumes that used for this study work has a maximum capacity to measure up to 9 l/s flow rate, from the graduated wall can read depth of flow in (m) and discharge rate in (l/s).

Furthermore, Cutthroat Flume has been also used to see the contribution of other water sources, relatively small flow rates; Kezikaze River, Muk Wuha, Tirngo and Wulko springs; to the main water source of Mile river for Jare SSI scheme.

4. House hold survey and key informant interviews

Issues related to production systems, organizations, community level problems and experiences have been collected through questionnaire, key informant interview and focus group discussions.

Sampling techniques

Totally 771HHs (537 HHs in Jari and 234 HHs in Aloma) beneficiaries have been used as a sample frame/population/ for the determination of sample size. Yamane (1967) provides a simplified formula to calculate sample sizes.

$$n = \frac{N}{1 + N(e)^2} \dots \dots \dots [3.3]$$

Where;

n= Sample size,

N= Population size/sample frame,

e= Level of precisions

For this study the calculation has been carried out through using 95% confidence interval ($\alpha=5\%$), 10% precision level and 50% degree of variability (P).

$$n = \frac{771}{1+771(0.1)^2} = 89\text{HHs}$$

Additionally by using proportionality percentage approach the sample size was distributed for both schemes; 60 & 29HHs for Jari and Aloma SSI schemes accordingly. The stratification has been carried out based on relative location and number of respondents to the irrigation schemes at head, middle and tail users. And respondents were selected through stratified systematic random sampling techniques from HHs beneficiaries list i.e., the number of respondents at each location were specified based on the number of beneficiaries in the block through proportional percentage. Simple random sampling technique has been used to select the respondent from each canal reaches. During sampling distribution time female headed households were also included purposively.

House hold survey

Before, conducting the interviewee the questionnaire was pre-tested (Appendix table 20). But at time of interviewee period farmers were not interested to exist at development agents office (DA's) based on the request. As result couldn't accomplished the number of HHs interviewees as we have planned/calculated. Thus due to this problem totally 48 (which 27 from Jari and 21 from Aloma) HHs were interviewed. From the respondents males account 34 and females 14.

Key informant interview and group discussion

Key informant interview was conducted from chair man of WUA; Vice chair man of WUA; three water user leaders (WUL) at head, middle and tail of the scheme; district agricultural and rural development office irrigation expert; and Kebele's irrigation and plant science experts (DA's). Generally 19 questions were prepared and 8 respondents in Jari and 6 in Aloma have been interviewed.

Additionally group discussion has been hold with WUA committees; three selected water user group leaders at head, middle and tail of the scheme; sex water users were selected by stratified proportional random sampling from head, middle and tail of the scheme (females were included); Kebele agricultural development agents (DA's); kebele administrative head and Kebele's court head. For group discussion purpose generally 24 types of questions were prepared. The discussion was carried out with 15 in Jari and 18 in Aloma participants for half day.

3.2.1.2. Secondary data collection

For Aloma SSI scheme the long time average climatic data of mean monthly minimum and maximum temperature and rain fall, were collected from Haik 3rd class meteorological station and the remain data of relative humidity, wind speed and sunshine hours were estimated from FAO LocClim1.0 software. While for Jari SSI scheme climatic data were estimated from nearby meteorological stations by using LocClim software. Additional secondary data of total command area, irrigable area, irrigated area, crop yield and price, agricultural inputs (fertilizers, chemicals, etc) were collected from Woreda and Zonal agricultural experts, DAs, reports, research publications and Design documents and from respective stakeholders.

3.2.2. Data Analysis Techniques

For data analysis and manipulation activities CROPWAT 8.0, GIS, SPSS, LocClim software's and Statistical tools were employed. Finally the selected performance indicators were computed.

3.2.2.1. Determination of crop water and irrigation water requirement

CROPWAT 8.0 computer program was used to estimate the total water requirements of major grown crops in the irrigation schemes. FAO (1992) Penman-Monteith method was selected to calculate the reference crop evaporation (ET_o). The model needs climatic, crop and soil data for the determination of crop water and irrigation requirements. To determine ET_o values the model requires climatic data; mean monthly minimum and maximum temperature (°c), relative humidity (%), wind speed (km/day) and sunshine hours (hr).

The amount of water required to compensate the evapo-transpiration loss from the cropped field is defined as crop water requirement. Although the values for Crop evapo-transpiration under standard conditions (ET_c) and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapo-transpiration refers to the amount of water that is lost through evapo-transpiration. The program estimates (ET_c) based on equation:

$$ET_c = ET_o * K_c \dots \dots \dots [3.4]$$

Where; K_c= crop coefficients, varies with a crop growing stages.

The value of K_c of each major crops were taken from FAO I & D 24 (1992) and 56 (1998) papers. The determination of irrigation requirement was made after estimation of effective rainfall by USDA Soil Conservation Service Method (Clarke *et al.*, 1998). Irrigation is required when rainfall is insufficient to compensate for the water lost by evapo-transpiration.

The primary objective of irrigation is to apply water at the right period and in the right amount. By calculating the soil water balance/budget of the root zone on a daily basis, the timing and the depth of future irrigations can be planned. In order to compute the irrigation water requirement, CROPWAT 8.0 computes a daily water balance of the root zone. Computed as;

$$IWR = ET_C - R_{eff} \dots \dots \dots [3.5]$$

And to estimate the total crop water requirement at scheme level input data of actual irrigated area by crop type was included.

3.2.2.2. Irrigation scheduling

For determination of irrigation schedule of the irrigation schemes and to make comparison with the current irrigation practices; moisture content, field capacity, permanent wilting point, depletion fraction at each growing stage data were collected. Additionally farmer’s irrigation practices were determined; such as irrigation methods, irrigation frequency and interval of irrigation, and application depths.

During the determination of the amount of water applied to the field, the average water flow rate to the farm inlet and respective time were recorded with the size of the fields being irrigated. The total volume of water applied to the field was obtained by multiplying the discharge rate with the inflow time. The depth of water applied to the field was obtained by dividing the total volume of water applied to the area irrigated.

The irrigation intervals at each growth stages of the main grown crops were determined procedurally through equations [2.1], [2.2] and [2.2]. Furthermore, through the determined irrigation intervals; the required depth of applications at each growth stages was determined by CROPWAT 8.0. Finally the irrigation schedules of main crops at both irrigation schemes were determined.

3.2.2.3. Performance indicators

Generally different groups of performance indicators; Water delivery indicator, On-farm water management indicators, financial, physical sustainability indicators and organizational performance indicators; have been used in this study to assess and compare the performance of the two small scale irrigation schemes at system levels. Under each group a number of minimum performance indicators have been used during evaluation.

1. Water delivery indicators

The water available for the irrigation systems at head, main canals, secondary canals and farm inlets have been computed from the measured data at the specified locations. Proper water distributions of the diverted amount of water at head to the whole irrigation system can be measured by water delivery performances of the existed irrigation infrastructures. The conveyance efficiencies of the main canals and secondary canals and the amount of losses per canal length at the specified locations were computed for each scheme.

A. Conveyance efficiency (CE)

Water distribution is the central importance of any management of irrigation systems. Conveyance system diverts water from its source, transports and distributes water to the point of use. As water is transported from the diversion site to the irrigation field, some amount of water is lost in different ways such as seepage and evaporation. Efficient irrigation system transports water with minimum losses and hence has high conveyance efficiency.

In order to determine the amount of water lost through conveyance system in the main canal, the amount of flow rate that enters to the main canal and amount of flow rate that leaves the main canal was measured. Water transport efficiency from the source to the field is measured by conveyance efficiency. The conveyance efficiency is used to evaluate the efficiency of the systems to conveying water.

$$CE = \frac{Q_{in}}{Q_{out}} \dots \dots \dots [3.6]$$

$$L = Q_{in} - Q_{out} \dots \dots \dots [3.7]$$

Where;

L= is conveyance loss (l/s),

CE= is conveyance efficiency (%),

Q_{in} and Q_{out}= are the inflow and outflow in specified canal reached length.

B. Relative water supply (RWS)

It was developed as a water supply indicator by (Levine, 1982). RWS indicates the adequacy of water applied to the amount of water demanded by the crop. It is the ratio of total water supplied by irrigation (I) and rainfall (P) to total water demanded by crop (i.e. actual crop evapotranspiration (ET_c)).

$$RWS = \frac{\text{Total Water supply}}{\text{Total Crop water demand}} \dots \dots \dots [3.8]$$

Where;

Total water supply= surface diversion plus effective rainfall (m³),

Crop water demand= potential ET, or the ET under well-water conditions for each crop (m³).

C. Relative irrigation supply (RIS)

This is the second water supply indicator and described as the ratio of irrigation supply to irrigation demand. Irrigation water is a scarce resource in many irrigation schemes and it is a major constraint for production. This indicator is useful to assess the degree of irrigation water stress/abundance/ in relation to irrigation demand (Molden et al., 1998).

$$RIS = \frac{\text{Irrigation supply}}{\text{Irrigation demand}} \dots \dots \dots [3.9]$$

Where;

Irrigation supply= only the surface diversion for irrigation (m³),

Irrigation demand= the crop ET less effective rainfall (m³).

RIS relates irrigation supply to irrigation demand of the irrigation schemes in the production season. The computed value shows some indication as the condition of water

abundance or scarcity, and how tightly supply and demand are matched. If the value greater than 1, it indicates irrigation supply was beyond the irrigation demand; if it is less than 1, the irrigation supply was below the irrigation demand. While if it is equal to 1, the supplied amount of irrigation was sufficient to demand, i.e. neither surplus nor deficit. Most of the time it is better to have a RIS near 1 than a higher value.

However the indicator did not show the monthly relation between irrigation supply and irrigation demand. Additionally care must be taken in the interpretation of results; the value 0.8 may not represent a problem; rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water.

2. On-farm Water management indicators

In this part agricultural output indicators and fertilizer utilization efficiency indicators; and under these a number of specific indicators have been employed.

i. Agricultural output indicators (water-land productivity)

A number of indicators are developed regard to irrigated agricultural systems. Water, land and finance are the main inputs for output of crop production. Five of them are relating to output to land and water were selected, i.e., two from land productivity and three from water productivity. These external indicators provide the basis for the comparison of irrigated agricultural performances. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important.

Output per unit irrigated cropped area (\$/ha):

It is computed as the total value of production per harvested area in the irrigation seasons. The harvested /Irrigated / area includes the areas that were irrigated in the irrigation seasons.

$$OPUIA = \frac{\text{Value of production}}{\text{Harvested cropped area}}, \frac{\$}{\text{ha}} \dots \dots \dots [3.10]$$

Output per unit command area (\$/ha):

This indicator quantifies the value of production that obtained per unit command irrigable area. The computed value indicates the level of utilization or number of cropping frequency of the given command area in the production year and the productivity of the command area. High value result shows there is good intensive irrigation. Meanwhile small values are not pertinent from land productivity point of view; less intensity of irrigation could not increase the production amount per unit of land. Furthermore this is more relevant for land is the major constraint factor for production. Command area is the nominal or design area to be irrigated.

$$OPUCA = \frac{\text{Value of production}}{\text{Production command(nominal)area}} \frac{\$}{\text{ha}} \dots \dots \dots [3.11]$$

Output per unit irrigation water diverted (\$/m³):

This is one of the water productivity indicators and calculated as the total value of production per unit water diverted from the headwork to the command area throughout the irrigation seasons; it includes the conveyance losses in the irrigation systems. It illustrates the productivity of diverted water from the source. It is an important parameter where water is a scarce resource. Diverted/supplied irrigation water is the volume of surface irrigation water diverted to the command area.

$$OPUIS = \frac{\text{Value of production}}{\text{Diverted Irrigation water}} \frac{\$}{\text{m}^3} \dots \dots \dots [3.12]$$

Output per unit irrigation water delivered (\$/m³):

It quantifies the value of production per unit delivered irrigation water to the head of farm inlets in the irrigation seasons. It is the net irrigation water delivered to the farm and 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. A lower value of this indicator indicates there is inefficient water use in the irrigation system or specifically at farm level.

$$OPUID = \frac{\text{Value of production}}{\text{Delivered irrigation water}} \frac{\$}{\text{m}^3} \dots \dots \dots [3.13]$$

Output per unit consumed water (\$/m³):

This indicator derived from the general water accounting frame work (Molden, 1998). Consumed water is the actual evapotranspiration or process consumption from only irrigated crops (ET); it excludes other losses and water depletion from the hydrological cycle. The computed value does not affected by water losses through the system but only affected by the climatic feature of the area. It used to observe water consumption of crops at scheme level through evapotranspiration relative to the diverted and delivered amount of irrigation water. It has a contribution for irrigation management aspects; to take measurements those minimize evapotranspiration losses.

$$OPUWC = \frac{\text{Value of production}}{\text{Volume of water consumed by ET}} \frac{\$}{m^3} \dots \dots \dots [3.14]$$

Value of Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices. In this study production from irrigated agriculture is the principal issue to compare systems. However there are difficulties when comparing different crops across a system, say Wheat and Potato, as 1kg of wheat is not readily comparable with 1kg of potato. When only one irrigation system is considered, or irrigation systems in a region where prices are similar, production can be measured as net value of production and gross value of production using local values.

As a result agricultural output production values were determined through local price and finally it was converted to US\$; to standardize and to compare the results relative to other research findings in the world.

ii. Fertilizer utilization efficiency (FUE) indicators

From a number of FUE performance measurements; due to data availability, level of interest and questions to be addressed; two indicators were selected for this study purposes. For computation purposes basic data; i.e. yields with and without fertilizer for selected crops, fertilizer rates (N and P) at each scheme were collected.

Partial factor of productivity (PFP):

Partial factor of productivity is a simple production efficiency expression, calculated in units of crop yield per unit of nutrient applied.

$$PFP = \frac{Yield}{Fertilizer\ used} \dots \dots \dots [3.15]$$

Agronomic efficiency (AE):

Agronomic efficiency indicator was calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return.

$$AE = \frac{Y - Y_0}{F} \dots \dots \dots [3.16]$$

Where,

Y= yield with fertilizer (kg),

Y₀= yield without fertilizer (kg)

F= fertilizer amount used (kg)

3. Physical performance indicators

Under this, two important physical performance indicators were selected to measure the sustainability and irrigation intensities of the systems.

A. Irrigation ratio

Sener *et al.* (2007) developed a relation between currently irrigated areas to the command (nominal) area to be irrigated; to quantify the level of utilization of the potential irrigable area for irrigated agriculture for a particular production time period. Lower utilization of the given irrigable area would be existed due to different constraints; i.e. lack of irrigation infrastructure, shortage of irrigation water, lack of interest on irrigation due to less return and market problems, and reduced productivity due to (soil nutrient depletion, lack of improved technologies, lack of inputs and water logging) etc. Furthermore cropping intensity is an illustrative for land utilization capacities. The cropping intensities from 100 to 200% are considered good, while lower ratio indicates poor intensities (Burton *et al.*, 2000).

To compute the indicator information's of irrigated areas in the irrigation season and designed irrigable areas of both schemes were collected from Agricultural and Rural development Offices.

$$IR = \frac{Irrigated\ area}{Command\ (nominal)\ irrigable\ area} \dots \dots \dots [3.17]$$

Where,

Irrigated area = irrigated area in the irrigation season (ha)

Command area= the design (nominal) irrigable area (ha)

B. Sustainability of irrigated area

According to Bos (1997) sustainability of irrigated area is the ratio of currently irrigable area to initially irrigated area. This important indicator mainly used to observe the status of the irrigation systems either contracted or expanded. If the computed value is small or less than 1 it shows the irrigable area is contracted and if it is large i.e. greater than one, it shows the irrigable area is expanded from the designed irrigable area, through including nearby farm areas. The contraction of irrigable land may be appeared due to different reasons, i.e. water shortage, water logging, flooding problems etc. On the other hand expansion might be occurred due to interests coming from neighboring farmers to irrigate extra land addition to designed one. This expansion of irrigable area indicates there is more sustainable of irrigation.

$$SIA = \frac{\text{Currently Irrigable area}}{\text{Initially irrigated area}} \dots \dots \dots [3.18]$$

Where,

Currently irrigable area= the area currently can be irrigated (ha)

Initially irrigated area= the designed/nominal/ irrigable area (ha)

4. Financial indicators

Due to lack of available data in this study only gross return on investment/GRI/ financial indicator was engaged.

$$GRI (\%) = \frac{\text{Gross value of Production}}{\text{Cost of irrigation infrastructure}} \dots \dots [3.19]$$

Where:

Gross value of production is the output production value of the irrigation projects (ETB/ha)

Cost of irrigation infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the production (ETB/ha)

Jari's SSI scheme irrigation infrastructure cost was taken from the design document; while in Aloma couldn't access the design document and the information was obtained from Tehuledere district Agricultural and Rural Development Office. Due to the absence of long term production data the gross investment return was calculated only for the production year of 2014/15. For computation purpose, the cost of irrigation infrastructure was estimated as present net worth (PNW), through the average interest rate of the service years.

$$PNW = p * (1 + i)^n \dots \dots \dots [3.20]$$

Where,

P= initial investment cost (ETB)

i= Average interest rate in the service years (%)

n= Number of service years

5. Organizational indicators

Organizational objectives, functions and structures of Water user association's (WUAs) were assessed. Under this organizational establishment, roles and functions, organizational structure and level of management starting from users to general assembly level were assessed. The responsibility at each level was identified. Finally the organizational structure and the level of management were indicated in map.

Water use fee amounts for members and non members; way of estimation and collection; final utilization status were clarified. Beneficiary's degree of participations in operation and maintenance activities and number of rounds for canal cleaning in the production year also assessed. Functionality of bylaws and internal rules and regulations and legal enforcement status was identified.

Water allocation at each organizational level, way of water allocation and gaps was clarified. Types of conflicts, causes of conflicts and conflict management experiences were assessed at each irrigation schemes.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Status of Irrigation Schemes and Irrigation Practices

4.1.1. Jari small scale irrigation scheme

Jari SSI scheme was constructed in 2005 and gave a service for 10years operational period. The initial command area of Jari SSI scheme was 168ha, however due to erosion problem in the area about 22ha land became out off production. Therefore, the total command area of the scheme is declined to 146ha. From the total command area irrigable land covers 125ha. The land holding of beneficiaries ranges from 0.01ha to 0.75ha. The command area was classified in 3 blocks and in 8 clustered farm blocks. Additionally for operation and management purpose the area was categorized into 12 water user groups.

The main canal length is about 1.1km and constructed in lined masonry. Despite some breaching of canals by illegal users, hydraulically the structure was under good condition. The secondary canal is lined masonry and each secondary canal has an average length of 500m. Hydraulically the structure was under good condition, but it was covered by weeds and soils. Additionally the tertiary canal is both lined masonry and earthen type.

In the irrigation scheme, there was cut-off drain structure constructed to divert Kezikaze River. This structure is currently not functional. As a result, the river over-flows into the farmland during the rainy season. In the irrigation scheme flow control gates (metal sheets) were installed in the whole irrigation system at division boxes or turnouts, but half of them became out off function and some of them are stolen.

The design document categorized the scheme under moderately vulnerable to soil erosion, but the area at present has been severely affected by erosion hazards (Appendix figure 10). Due to erosion and sedimentation problems from the uphill of the watershed, the cultivated land regularly covered by debris and stones during the rainy season and hindering farming activities, as well as reducing the productivity of farm land.

The irrigation scheme was constructed to provide as a demonstration site for fruit and vegetable productions. During design period fruits (orange, banana, mango, avocado and sugar cane) and vegetables (tomato, pepper and onion) were recommended for production in the irrigation scheme. Farmers practice different irrigation methods. Flooding type of

irrigation is widely practiced for the main crops, while at initial stage of growing period farmers have tried to practice furrow irrigation method for maize, pepper, onion and cabbage crops. For sugar cane cultivation they use furrow irrigation and for fruit trees they use basin irrigation. Rigid rotational irrigation schedule has been practiced in the irrigation scheme and most of the time it takes 15 days for one cycle/rotation/.

4.1.2. Aloma small scale irrigation scheme

Aloma SSI was constructed in 2012 and only gave service for the last 3 years. The designed command area was 210ha; that located in 08 and 09 kebeles. However, currently only 115ha is irrigable in Kebele 08. From the command area 90ha was irrigated in the irrigation season. The land holding of beneficiaries ranges from 0.25ha to 1ha. For operation and management purpose the command area has 3 clustered farm blocks and 7 water user groups.

The main canal total length is about 1.5km; which contains 200m earthen canal, 1 small and 3 large transmitting metal flumes of 170m length and the remain is lined masonry. Hydraulically the main canal was under good condition; except the earthen type canal and some flume leakages. The secondary canal is constructed in lined masonry and each canal has an average length of 350m. However most of the secondary canals were cracked, broken and silted by weeds and soils. While the irrigation scheme has no tertiary canals, instead farmers uses field canals and directly from secondary canals.

The irrigation scheme has no any water flow control gates at division boxes or turnouts; as an alternative farmers have uses local control materials (stone, soil, sacks filled with soil/sand) (Appendix figure 9). The slope of secondary canal is high. As a result there are some difficulties to divert the required amount of water from secondary canal through use the local flow control materials.

Carrot, cabbage, garlic, onion, tomato and maize were the major crops recommended for production during design period. However, currently farmers have been dominantly producing cereal crops. Farmers produce single cropping system by using irrigation. Flooding irrigation method is widely practiced. But farmers use furrow irrigation for potato at initial growing period, in the interim it shifted to flooding irrigation (Appendix 11). Partially flexible rotational irrigation has been practiced in the irrigation scheme.

Farmers were not used the irrigation scheme for 1 year after construction was completed, because farmers have had frustration on their land, ‘the nutrient will be depleted exhaustively when they use irrigation’. Meanwhile the District Agriculture and Rural Development Office had tried to create awareness and convinced them to produce carrot in 2014. But due to market problem farmers have not benefited. The situation contributes for low utilization of the irrigation scheme at present.

4.2. Characteristics of the Irrigation Schemes Beneficiaries

For the assessment of socioeconomic characteristics of the irrigation schemes household survey was conducted at each irrigation scheme. According to the result of this survey 77.8% and 85.7% of the beneficiaries were male headed households in Jari and Aloma irrigation schemes, respectively (Table 4.1).

About 92.6% and 90.5% of the beneficiary household heads age was in the range of 21-65 years at Jari and Aloma irrigation schemes. The average family size was 5 at both irrigation schemes. Regarding to educational level, about 37% of the beneficiary household heads at Jari were illiterate. On the other hand, about 42.9% of beneficiary household heads in Aloma irrigation scheme attended elementary school. Above 92% of the beneficiary households in both irrigation schemes were married.

Table 4.1: Socio-demographic characteristics of beneficiary household heads

Characteristics		Schemes			
		Jari (N=27)		Aloma (N=21)	
		Frequency	(%)	Frequency	(%)
Sex	Male	21	77.8	18	85.7
	Female	6	22.2	3	14.3
Age of HH heads	21-65 years	25	92.6	19	90.5
	>65 years	2	7.4	2	9.5
Educational level	Illiterate	10	37	7	33.3
	Read and write only	9	33.3	4	19
	Elementary	6	22.2	9	42.9
	High school	2	7.4	1	4.8
Marital status	Married	25	92.6	20	95.2
	Widowed	1	3.7	-	-
	Divorced	1	3.7	1	4.8

Source: HHs field survey where, N= number of respondents, HH= Household

The major occupation of the households in each irrigation scheme was smallholder mixed farming system (combination of crop, vegetable and livestock productions), 66.7% in Jari

and 52.4% in Aloma. However in Aloma SSI scheme, 47.6% of the respondent's major occupations were also crop production. From the respondents 92.6% in Jari and 95.2% in Aloma reflected that they had no any additional incomes that supplement their major occupations of the households.

Even though rainfall has been erratic distribution and insufficient for agricultural production in the areas, but interviewed household's agricultural production for the last three years was sufficient for annual household consumptions, 66.7% in Jari and 71.4% in Aloma. This might be an indication of how much irrigation development plays a major role to secure household food needs.

All respondents have believed that the irrigation scheme was important and increased their annual incomes relative to the annual income before the project. From the respondents in Jari 48.1% and 33.3% estimated that their annual income was increased by 100% and 50% respectively. In Aloma 57.1% and 23.8% of the respondents believed their annual income increased by 100% and 50% accordingly.

However, in Aloma around 23.8% of the respondent's agricultural production was sufficient for only 6 months household consumption, it implied that there was food gaps in the remaining months. The reason was most farmers were dependent on rainfall to produce crops. Consequently leads to low production by using irrigation. As a result in this scheme, increasing agricultural production through intensifying irrigation agriculture is the first priority.

4.3. Factors Affecting Irrigated Crop Production

Water, market and crop damage were the main three factors which affects irrigated crop productivity in Jari irrigation scheme; water accounts 33.3% of the production constraint. According to the respondent's evaluation credit, absence of government support and transport were not important in determining their irrigated crops productivity at Jari SSI scheme.

In Aloma market, water and land were the three primary factors that affect irrigated crop production; from the respondents 52.4% of them have been ranked market was the dominant constraint factor. In this irrigation scheme lack of skill, absence of governmental support and transport were not the main problems for irrigation agriculture.

Table 4.2: Farmers rank of factors affecting irrigated crop production at Jari and Aloma irrigation schemes

Factors	Jari			Aloma		
	Frequency	Percents	Rank	Frequency	Percents	Rank
Water	9	33.3	1	4	19.0	2
Land	3	11.1	4	3	14.3	3
Input	1	3.7	5	1	4.8	4
Credit	-	-	-	1	4.8	4
Market	6	22.2	2	11	52.4	1
Crop damage	5	18.5	3	1	4.8	4
Lack of skill	3	11.1	4	-	-	-
Absence of gov't support	-	-	-	-	-	-
Transport	-	-	-	-	-	-
Total	27	100.0		21	100.0	

Source: HHs field survey

4.4. Rainfall Data Analysis

The rain fall distributions in both study areas showed a bimodal rainfall pattern. In Jari SSI scheme the minimum and maximum rainfall amount occurs in months of November (26.9 mm) and July (229 mm), respectively. The maximum rainfall at Aloma SSI scheme occurs in month of July (341mm); while the minimum one occurs in January (19.3 mm).

Jari irrigation scheme has an average total annual rainfall of 1,066 mm that is lower than Aloma's scheme (1,202 mm). Conversely the average total annual effective rainfall amount of Jari (817 mm) is more than Aloma's (798 mm). Thus the amount of runoff was high in Aloma irrigation scheme. This might arises due to undulating topography /gentle slope of the area, soil type /clay soil/ and high rainfall intensities.

In Jari SSI scheme 151 mm and 249 mm average total effective rainfall was available in the first irrigation season (November-February) and in the second irrigation season (March-June) respectively. While in Aloma SSI scheme, from one irrigation season (March-June), 261mm average total effective rainfall was available.

Both study sites are characterized as moisture stress areas. From the respondents 62% and 50% revealed that, rainfall was insufficient in amount for crop production for the last three years, at Jari and Aloma SSI schemes, respectively. Despite the variability of rainfall distribution in time and space; the amount of rainfall received in 'Belg' season (February-June) has significant impact for crop production in the irrigation season. As well it has an advantage to minimize conflicts that may arise due to water shortage at

critical irrigation months. Hence this effective rainfall contributed to support the crop water demand in the irrigation seasons. Furthermore, the detailed advantage of this amount of rainfall is discussed in water delivery and water productivity performance indicators section.

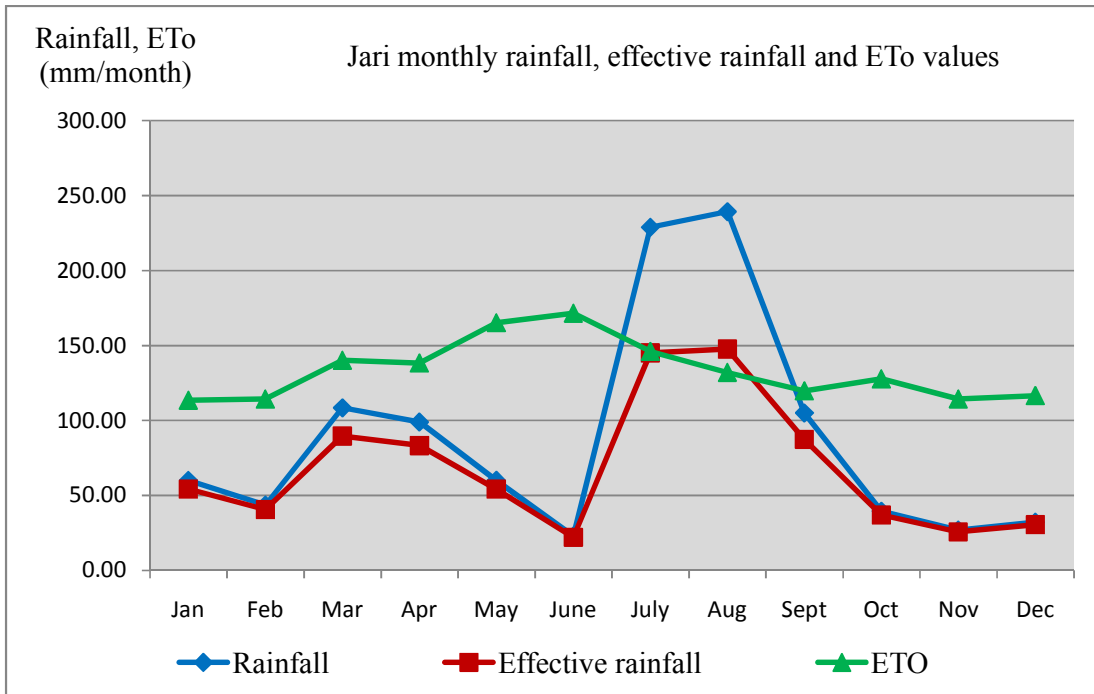


Figure 4.1: Jari SSI scheme mean monthly rainfall, effective rainfall and ETo values

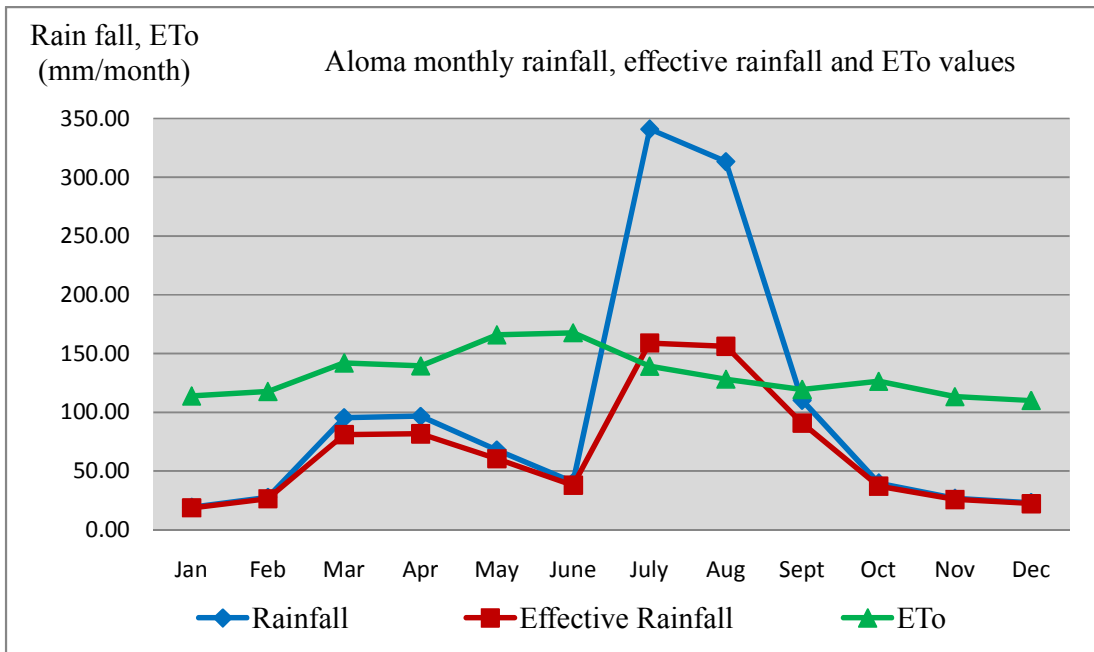


Figure 4.2: Aloma SSI scheme mean monthly rainfall, effective rainfall and ETo values

4.5. Determination of Reference Evapo-transpiration (ET_o)

Based on the procedure described in the methodology part, ET_o values of the two schemes were computed. Summary of meteorological data and computed values are listed (Figure 4.1 & 4.2) and (Appendix table 3 and 4).

The minimum and maximum daily ET_o values of Jari irrigation scheme were 3.66 mm/day in January and 5.72 mm/day in June. In Aloma the maximum ET_o was estimated 5.59 mm/day at month of June and the minimum was 3.55 mm/day in December. The estimated average daily ET_o values of Jari and Aloma SSI schemes were 4.38 and 4.34 mm/day, respectively.

As indicated in figure 4.3, in Jari irrigation scheme the mean monthly ET_o values are much higher than that of mean monthly effective rainfall except at months of 1st July to 1st August but the difference is smaller at these 2 months. In Aloma the mean monthly ET_o values are above the mean monthly effective rainfall expect starting from 1st July to 15 August it is under lay (Figure 4.2). As a result extra water is required to full fill the evapotranspiration demands of the environment. However, to increase water productivity in irrigation agriculture, it needs to select crops which have low evapotranspiration demand and irrigation methods with minimum evaporation losses.

4.6. Cropping Pattern of the Irrigation Schemes

Cropping pattern of a certain area mainly depends on availability of water, type of soil and land to be irrigated, climatic conditions, and also value of produce/market/ and socioeconomic aspects. From the household survey results, in Jari 56% of the respondents, revealed that they have been practiced double cropping system in the irrigation seasons; i.e. the first is from November to February and the second from March to June.

While in Aloma, the whole respondents, 100% reflected that they have been practiced only single cropping system in the irrigation season, which is from March to June. In Jari around 55.6% of the respondents have been selected grown crops by considering the productivity of the crop and in Aloma 42.9% considered from market price point of view.

Maize, teff, pepper, onion, tomato, cabbage and chick pea were the main crops cultivated in the irrigation seasons in Jari. From fruit trees mango, avocado, orange, banana and

sugar cane are under cultivation. In Aloma wheat, teff, potato, onion, chick pea, maize and haricot bean are the main crops that were cultivated in the irrigation season.

Table 4.3: Farmers crop selection criteria

Criteria	Jari			Aloma		
	Frequency	percent	Rank	Frequency	percent	Rank
Better price	7	25.9	2	9	42.9	1
Easy to operate	5	18.5	3	4	19.0	3
Good production	15	55.6	1	7	33.3	2
High disease tolerance	-	-	-	1	4.8	4
Total	27	100	-	21	100	-

Source: HHs field survey

Table 4.4: Crops area coverage and LGP at Jari and Aloma SSI schemes

Jari SSI							
S. No	Type Crops	Irrigation seasons					
		Season I			Season II		
		Area (%)	Area (ha)	LGP (days)	Area (%)	Area (ha)	LGP (days)
1	Chick pea	33	33.7	90	-	-	-
2	Green maize	27	27.5	90	24	27.6	90
3	Pepper	20	20.4	120	10	11.5	120
4	Mango**	5	5.1	273	-	-	-
5	Avocado**	3	3.1	273	-	-	-
6	Orange **	4.5	4.6	273	-	-	-
7	Banana**	2.5	2.6	273	-	-	-
8	Sugar Cane*	5	5.1	273	-	-	-
9	Teff	-	-	-	35	40.3	100
12	Tomato	-	-	-	4.25	4.9	115
13	Onion	-	-	-	5	5.8	100
14	Cabbage	-	-	-	4	4.6	120
Total		100	102		82.25 (#18)	94.6 (20.5#)	

Aloma SSI							
1	Teff	-	-	-	36	32.4	110
2	Wheat	-	-	-	40	36	115
3	Potato	-	-	-	6.5	5.85	120
4	Chick pea	-	-	-	9	8.1	100
5	Green maize	-	-	-	6	5.4	105
6	Haricot bean	-	-	-	2.5	2.25	100
Total					100	90	

Where; *Annual crops **Perennial crops LGP= Length of growing period

Areas covered by annual and perennial crops in the second irrigation season.

4.7. Soil Data Analysis Results

Soil samples were taken at depth of (0-30 and 30-60cm) to investigate the physical and chemical properties of the irrigation schemes. From the sampled soil texture, field capacity (FC), permanent wilting point (PWP), organic matter content (OM) and macro nutrients (N and P) were analyzed.

4.7.1. Soil textural class and nutrient contents

The soil textural class of both irrigation schemes was determined based on the particle size distribution through using USDA SCS Soil Textural Triangle method (Appendix figure 1). As indicated in table 4.5 the soil texture distribution was slightly varied at Jari irrigation scheme. Clay Loam soil type was found in the head and tail of the scheme; while the dominant soil type in the middle of the scheme was clay soil type. In Aloma irrigation scheme clay soil type was more dominant in head and middle of the scheme but clay loam was dominant in the tail part of the scheme.

Table 4.5: Soil textural classes of the irrigation schemes

Irrigation schemes	Canal reaches	Soil depth (cm)	Particle size distribution (%)			Textural class
			Clay	Silt	Sand	
Jari SSI	Head	0-30	33	37	30	Clay loam
		30-60	38	32	30	Clay loam
	Middle	0-30	41	39	20	Clay
		30-60	49	35	16	Clay
	Tail	0-30	35	40	25	Clay loam
		30-60	49	29	22	Clay
Aloma SSI	Head	0-30	49	27	24	Clay
		30-60	47	33	20	Clay
	Middle	0-30	47	33	20	Clay
		30-60	42	32	26	Clay
	Tail	0-30	20	48	32	Clay loam
		30-60	35	40	25	Clay loam

The sampled soil organic matter (OM), total nitrogen (N) and available phosphorous (P) contents were described in table 4.6 and 4.7. The computed values of OM and N nutrients were rated based on Tekalign (1991) soil nutrient content classification method. While rating of soil available phosphorous was carried out accordance with Cottenie (1980) recommended classification approaches.

Table 4.6: Soil OM and total N contents at Jari and Aloma SSI schemes

Irrigation schemes	Canal reaches	Soil depth (cm)	Nutrient contents			
			OM (%) ^a	Ratings	N (%) ^a	Ratings
Jari SSI	Head	0-30	1.57	Low	0.19	Moderate
		30-60	2.00	Low	0.18	Moderate
	Middle	0-30	1.77	Low	0.16	Moderate
		30-60	1.94	Low	0.19	Moderate
	Tail	0-30	2.10	Low	0.19	Moderate
		30-60	1.73	Low	0.16	Moderate
Aloma SSI	Head	0-30	1.97	Low	0.17	Moderate
		30-60	1.26	Low	0.21	Moderate
	Middle	0-30	2.38	Low	0.16	Moderate
		30-60	1.87	Low	0.19	Moderate
	Tail	0-30	2.15	Low	0.18	Moderate
		30-60	1.67	Low	0.20	Moderate

Table 4.7: Soil available phosphorous analysis results

Irrigation schemes	Canal reaches	Soil depth (cm)	Nutrient contents	
			P (mg/kg) ^b	Ratings
Jari SSI	Head	0-30	7.62	Low
		30-60	6.91	Low
	Middle	0-30	5.95	Low
		30-60	5.70	Low
	Tail	0-30	6.27	Low
		30-60	8.06	Low
Aloma SSI	Head	0-30	6.54	Low
		30-60	7.10	Low
	Middle	0-30	6.53	Low
		30-60	7.30	Low
	Tail	0-30	6.53	Low
		30-60	7.86	Low

Source: ^a Tekalign (1991) classification method; ^b Cottenie (1980) classification method

4.7.2. Soil field capacity and permanent wilting point

Computed soil moisture characteristics values of field capacity (FC), permanent wilting point (PWP) and total available water content (TAW) are indicated in table 4.8. The total available moisture content values in Aloma irrigation scheme ranges from 98.7 to

136.9mm/m for clay and clay loam soils, respectively. In Average the moisture holding capacity of Jari's soil was better than Aloma's.

However, the total available water or water holding capacity of the soil at both irrigation schemes was poor. In general, the relative magnitude of water holding capacity of the soil depends on its textures and structures. As a result, the low water holding capacity of the soil can affect crop water productivity of the irrigation schemes. Thus it needs to improve the soil structures at both irrigation schemes through proper managements; include addition of organic matter, adopting of suitable tillage, soil conservation and cropping practices /rotations/.

Table 4.8: Soil FC, PWP and TAM of the irrigation schemes

Irrigation schemes	Canal reaches	Soil depth (cm)	FC (%)	PWP (%)	TAW (%)	TAW (mm/m)
Jari SSI	Head	0-30	34.63	21.40	13.23	132.3
		30-60	36.51	24.03	12.48	124.8
	Middle	0-30	41.40	29.51	11.89	118.9
		30-60	41.20	31.16	10.04	100.4
	Tail	0-30	37.50	21.50	16.00	160.0
		30-60	43.06	31.32	11.74	117.4
Average						125.63
Aloma SSI	Head	0-30	42.77	31.82	10.95	109.5
		30-60	43.88	32.77	11.12	111.2
	Middle	0-30	40.75	30.73	10.02	100.2
		30-60	39.79	29.91	9.87	98.7
	Tail	0-30	34.16	20.68	13.48	134.8
		30-60	35.18	21.49	13.69	136.9
Average						115.2

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

4.7.3. Soil infiltration rate

The constant infiltration rates of 2.0 cm/hr and 1.4 cm/hr; after 2.4 hrs and 2.56 hrs of test at field conditions; were computed in Jari and Aloma SSI schemes respectively. The observed test values are indicated in appendix figure 3 and 4. As discussed earlier the dominant soil types in the irrigation schemes were clay loam and clay soils for Jari and Aloma, respectively. Besides to this, the observed infiltration rates of the above soil textural classes were greater than the recommended ranges. The reasons might be related to the borrowing of soil profile but in general couldn't capture the exact problems for

high infiltration rates. As a result it is better to use the average recommended values for inputs in CROPWAT model, i.e. 0.75 cm/hr for clay loam and 0.3 cm/hr for clay soils.

Table 4.9: FAO recommended infiltration value for basic soil types

S.no	Soil type	I (cm/hr)
1	Sand	<3
2	Sandy loam	2-3
3	Loam	1-2
4	Clay loam	0.5-1
5	Clay	0.1-0.5

I= basic infiltration rate

4.8. Determination of Crop Water Requirements and Irrigation Requirements

CROPWAT 8.0 model computed the crop water requirements based on equation [3.4] and it needs climatic data for ETo computation, crop characteristics data and soil description for the determination of crop water requirements and irrigation water requirements. Crop water requirements are defined as the depth of water needed to meet the water loss through evapotranspiration. It was determined for the main crops grown in both irrigation schemes based on equation [3.4]. The main crops grown in the irrigation seasons have been identified for both schemes (Table 4.4).

Description of crop characteristics; i.e., planting date and length of growing period (LGP) were collected from household survey results. Perennial crop's length of growing periods were fixed for the computation of water demands in the irrigation seasons. Crop coefficient (Kc), maximum root depth (m), crop height, yield reduction factor (Ky) values were adopted from FAO Irrigation & Drainage paper 24 and 56, the detailed values in growth stage based are described in (Appendix table 18 and 19). The values of Kc in the growing period are represented by crop coefficient curve, the values varies in the growing period. The CROPWAT model required the three Kc coefficients (Kc of initial, development and late stages).

Furthermore, the allowable soil moisture depletion fraction for each crops at each growing stage were adopted from FAO I & D paper 24 and 56, and research documents. Allowable moisture depletion fraction is a critical soil moisture level where the first drought stress occur affecting evapotranspiration and crop production. The fraction normally varies from 0.2-0.6 with the lower value being for sensitive crops with limited

rooting systems. To estimate yield reductions associated with drought stress, yield response factor (Ky) was given as an input variable in the crop data option.

Through the above input data the total crop water and irrigation water requirements were computed for the estimation of total water demands at the irrigation schemes in the growing seasons. The net scheme irrigation requirement (NSIR) in the growing season, in monthly bases was also determined for a given cropping pattern of the irrigation schemes. NSIR showed the total monthly irrigation demand of the irrigation schemes.

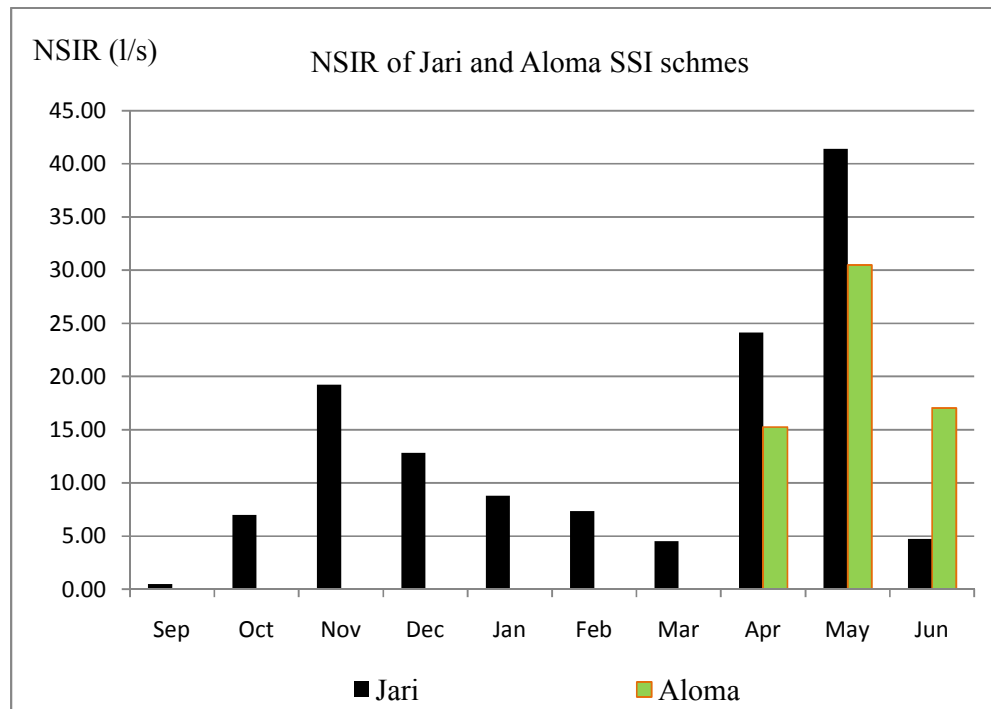


Figure 4.3: Net scheme irrigation requirement at both schemes

Table 4.10: Crop water and IR of Jari and Aloma irrigation schemes

Scheme	Season	Irrigated Crops	Area	CWR (mm/season)	R.eff (mm/season)	NIR (mm/season)	
Jari	Season I	Chick pea	33.66	259.2	115.3	163.5	
		Maize	27.54	296.3	107.4	185.7	
		Pepper	20.4	409.0	151.2	257.8	
		Mango	5.1	1194.3	502.7	691.6	
		Avocado	3.06	1194.3	502.7	691.6	
		Orange	4.59	1194.3	502.7	691.6	
		Banana	2.55	1326.8	502.7	824.1	
		Sugar Cane	5.1	1169.8	502.7	705.4	
	Total		102				
	Season II	Teff	40.3	351.3	231.8	158.4	
		Maize	27.6	393.6	224.3	187.6	
		Pepper	11.5	534.7	256.3	279.4	
		Tomato	4.9	514.5	255.7	268.4	
		Onion	5.8	461.2	231.8	228.2	
Cabbage		4.6	552.9	256.3	297.7		
Total		94.6					
Aloma	Season II	Teff	32.4	402.3	238.1	195.6	
		Wheat	36	499.5	245.7	277.2	
		Potato	5.85	556.4	256.5	302.4	
		Maize	8.1	490.0	235.2	267.7	
		Chick pea	5.4	360.7	231.3	162.8	
		Haricot bean	2.25	434.3	231.3	215.0	
Total		90					

Where; NCWR- Net crop water requirement NIR- Net irrigation requirement R.eff- effective rainfall

The total net crop water requirement/demand/ for season I in Jari SSI scheme;

$$\begin{aligned}
 CWR_I = & CWR_{chick\ pea} * \left(\frac{A_{chick\ pea}}{A_{total}} \right) + CWR_{maize} * \left(\frac{A_{maize}}{A_{total}} \right) + CWR_{pepper} \\
 & * \left(\frac{A_{peppr}}{A_{total}} \right) + CWR_{Mango} * \left(\frac{A_{Mango}}{A_{total}} \right) + CWR_{Avocado} \\
 & * \left(\frac{A_{Avocado}}{A_{total}} \right) + CWR_{Orange} * \left(\frac{A_{Orange}}{A_{total}} \right) + CWR_{Banan} \\
 & * \left(\frac{A_{Banan}}{A_{total}} \right) + CWR_{sugar\ cane} * \left(\frac{A_{sugar\ cane}}{A_{total}} \right)
 \end{aligned}$$

$$\begin{aligned}
CWR_I &= 259.2 * \left(\frac{33.66}{102}\right) + 296.3 * \left(\frac{27.54}{102}\right) + 409 * \left(\frac{20.4}{102}\right) + 1194.3 * \left(\frac{5.1}{102}\right) \\
&+ 1194.3 * \left(\frac{3.06}{102}\right) + 1194.3 * \left(\frac{4.59}{102}\right) + 1326.8 * \left(\frac{2.55}{102}\right) \\
&+ 1169.8 * \left(\frac{5.1}{102}\right)
\end{aligned}$$

$$\begin{aligned}
CWR_I &= 85.5 + 80 + 81.8 + 59.7 + 35.8 + 53.7 + 33.2 + 58.8 \\
&= \mathbf{488.3mm/season}
\end{aligned}$$

The total net crop water requirement/demand for season II was;

$$CWR_{II} = 149.5 + 114.8 + 65 + 26.6 + 28 + 26.9 = \mathbf{410.9mm/season}$$

With similar computation procedures the total net irrigation requirements of the two seasons; and the total net crop water requirement and the total net irrigation requirements of Aloma were determined (Table 4.11).

Table 4.11: NCWR and NIR per season for Jari and Aloma SSI schemes

Scheme	Season	NCWR (mm/season)	NIR (mm/season)	R.eff (mm/season)	NCWR (m ³)	NIR (m ³)	R.eff (m ³)
Jari	Season I	488.3	298.0	197.8	498050	303936	201784
	Season II	410.9	198.3	235.3	388621	187598	222267
Aloma	Season II	457.4	240.2	241.5	411654	216169	217347

Where; NCWR- Net crop water requirement NIR- Net irrigation requirement R.eff- effective rainfall

4.9. Water Flow Rate Measurement

It was quite difficult to measure water flow rates continuously from intake to farm inlets; because there was flow fluctuations, the farmer uses rotational scheduling systems, and sometimes there were water abstractions in the upstream/illegal water users/, and absence of reliable and functional flow control systems at each division boxes.

4.9.1. Flow rate measurement at Jari SSI Scheme

As observed in figure 4.4 (a) and (b); there were weekly and monthly flow variations at the intake across the irrigation season. The weekly record in the second irrigation season has been interrupted for two weeks; water was not released into the canal; due to the occurrence of rainfall in (15/5/2015 and 22/5/2015).

The flow fluctuation was high in the case of weekly records. The possible reasons were; firstly in week 8 there was a maximum flow rate of 52.1 l/s at intake due to the existence of rainfall in the upper stream of Ambassel highlands. Secondly in week 11, the maximum flow rate 54 l/s was recorded after rain fall cessation in the area. These two flow records were contributed for high flow variations.

Furthermore, the variation might be existed from the way of farmer’s diversion at the head and the amount of upstream users released (Jari-Full Wuha irrigation scheme in the left side direction). Additionally diversion intake has not been gated; instead it was fenced with mesh metal bars to protect derbies; it has side effect for full flow of water to the system. It collects derbies, sands and river boulders and it clogs intake. Beside this, 48% of the respondents indicated that there has been access of irrigation water for 4-6 months time period, i.e. starting from October to March. However the tail users faced difficulties to access irrigation water after March.

Table 4.12: Respondents evaluation on length of months to access irrigation water

Months	Responses (%)							
	Jari SSI scheme				Aloma SSI scheme			
	Head	Middle	Tail	Total	Head	Middle	Tail	Total
For 1-3 months	0.0	0.0	11.1	11.1	0	0	4.8	4.8
For 4-6 months	7.4	29.6	11.1	48.1	14.3	33.4	19	66.7
For 7-9 months	14.8	25.9	0.0	40.7	19	9.5	0	28.5
Total	22.2	55.6	22.2	100.0	33.3	42.9	23.8	100

Source; HHs field survey

The monthly flow variations at the intake across the irrigation seasons; starting from September to June was generated from; weekly records and informally from WUA committees and house hold survey results. The WUA’s committees during group discussion estimated that the flow amount at December decreased by 15-20% up to month of March. And they described the maximum flow occurs in September and October, and it decrease up to March until the short rainy season begins. The monthly flow variation of 12% was existed in January and February successively.

Additionally for comparison and justification purposes two time flow measurement were taken after one year of similar months. Furthermore the two times record taken in December, 2015 indicates that 38 l/s flow amount was existed. By considering the above circumstances the monthly flow amounts were generated through linear forecast trend

line approaches (Figure 4.4.b). Furthermore the rain fall that occurred in May was highly affected the trend of flow and the record amounts.

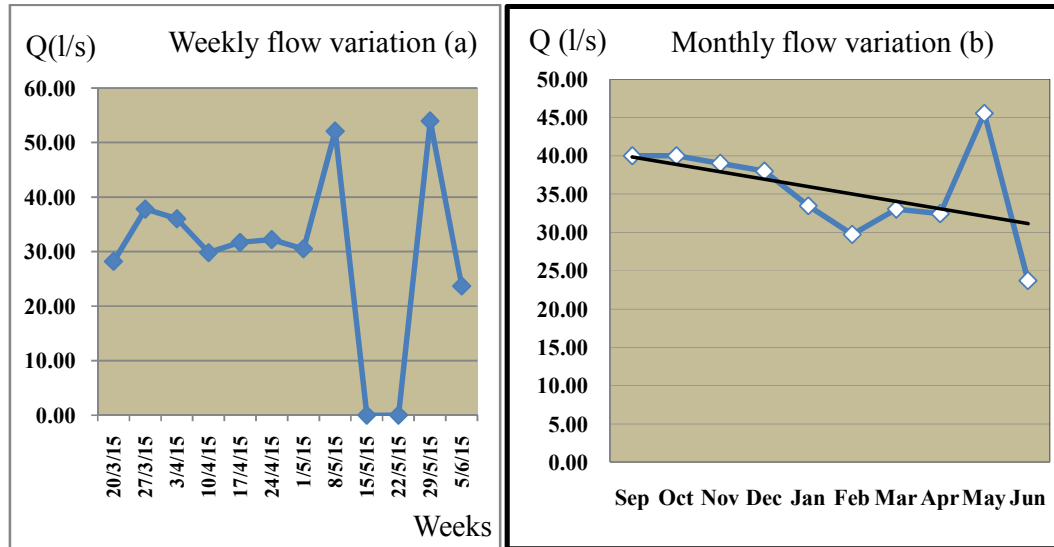


Figure 4.4: Weekly and monthly flow rate variations at Jari intake

Table 4.13: Mean flow rate at the diversion site of Jari and Aloma irrigation schemes

	Jari SSI		Aloma SSI	
	Weekly	Monthly	Weekly	Monthly
N	10	10	10	10
Mean	35.62	35.49	58.16	55.42
SE	3.16	1.98	1.72	1.33
CV (%)	99.74	39.08	14.72	17.65

Where; N= number of observation, SE= standard error, SD= standard deviation and CV= coefficient of variance

With similar approaches the mean in-flow and out-flow rates at main canal and secondary canals were estimated. As indicated in table 4.14; the results of 40 different observations that taken from five locations in the main canal, revealed that there was 28.21 l/s mean out-flow rates from main canal at Jari SSI scheme. Additionally in secondary canals a mean out-flow of 26.4 l/s was investigated from 16 observations at Jari irrigation scheme.

Table 4.14: Mean flow rate, CE and losses at the main and secondary canals of Jari

	Canal Locations							
	Main canal				Secondary canal			
	Q _i (l/s)	Q _o (l/s)	CE	Losses (l s ⁻¹ /m)	Q _i (l/s)	Q _o (l/s)	CE	Losses (l s ⁻¹ /100m)
N	40	40	40	40	16	16	16	16
Mean	35.62	28.21	0.79	0.016	29.9	26.4	0.87	0.71
SE	3.16	2.92	0.081	0.0011	2.25	2.22	0.01	0.05

Where; N-Number of observations

SE- Standard error

4.9.2. Flow rate measurement at Aloma SSI scheme

Likewise, in Aloma irrigation scheme the record has been interrupted for two weeks; water was not released in the canal; due to the occurrence of rainfall in (9/5/2015 and 16/5/20015). As showed in the figure 4.5 (a); the flow variation was slight, CV of 14.72%, shows the decreasing trend in the irrigation season. In this irrigation scheme a maximum flow 62.4l/s was recorded in 23/5/2015 immediately after the cessation of rainfall.

Despite farmers have not used the first irrigation season; from the respondents 66.7% of them described that irrigation water is more accessible up to 6 months, starting from October to March. To synthesize the situation and to show the water availability; a monthly flow was generated from weekly mean flow records and through farmer's local experience and knowledge about the flow variability in the canal. Additionally the mean in-flow and out-flow rates at main and secondary canals were estimated; the mean out-flows of 49.15 l/s and 32.60 l/s were recorded from main and secondary canals, respectively.

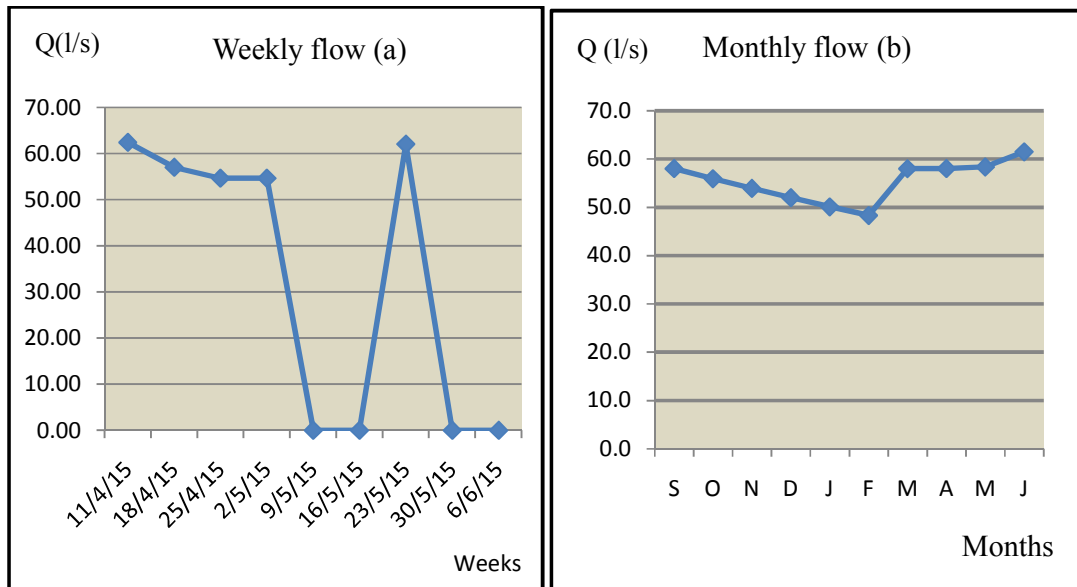


Figure 4.5: Weekly and monthly flow rate variations at Aloma intake

Table 4.15: Mean flow rate, CE and L at the main and secondary canals of Aloma

	Canal Locations							
	Main canal				Secondary canal			
	Q _I (l/s)	Q ₀ (l/s)	CE	Losses (l/s ⁻¹ /m)	Q _I (l/s)	Q ₀ (l/s)	CE	Losses (l/s ⁻¹ /100m)
N	25	25	25	25	10	10	10	10
Mean	58.2	49.15	0.85	0.011	40.98	32.60	0.79	2.40
SE	1.72	2.79	0.05	0.002	0.65	0.86	0.01	0.13

Where; N-Number of observations, SE- Standard error, Q_I=inflow, Q₀= outflow, CE=conveyance efficiency

4.9.3. Water flow rate measurement at farm inlets

In Jari irrigation scheme most of the time, but not always, farmers split the released water from secondary canal into two directions; to use it effectively and for management purposes. The measured observations indicated that a mean in-flow rate of 16.32 l/s was reached to the farm inlets. For the computation of total diverted flow to the command area in Jari, sum of mean flow of 35.49 l/s from Mile River and as well from other sources of (Muk Wuha, Tringo and Wulko springs, and Kezikazie River of 3.2, 0.75, 1.25 and 3.75 l/s) were used respectively.

In the case of Aloma SSI scheme the total inflow that came through the main canal divided into two secondary canals. Measurements in farm inlets showed that a mean of 21.17 l/s inflow rate was recorded.

The above two mean inflow rates were used for the determination of total water delivered to farm fields at both irrigation schemes. In Jari SSI scheme farmers have been practiced two irrigation seasons; the amount of diverted and delivered water in this scheme were the total sum of the two irrigation seasons for the year 2014/15 from all water sources. In Aloma SSI scheme farmers have been practiced one irrigation season; from March to June. Thus the total diverted and delivered amounts of water to the command area would be from this season only.

Table 4.16: Mean command area, discharge rate and duration of irrigation at Jari and Aloma SSI schemes

	Jari SSI				Aloma SSI			
	A (ha)	Q (l/s)	T (hr)	Depth (mm)	A (ha)	Q (l/s)	T (hr)	Depth (mm)
N	36	36	36	36	36	36	36	36
Mean	0.21	16.32	1.16	33.29	0.383	21.17	1.215	67.16
SE	0.02	0.10	0.14	1.07	0.041	0.56	0.29	0.3

Where; N-Number of observations, SE- Standard error A= Area, Q= Flow rate, T= duration

Table 4.17: Computed values of diverted and delivered volume of water for Jari and Aloma SSI schemes

Scheme	Season	Diverted/supplied (m ³)	Delivered (m ³)
Jari	Season I (Nov-Feb)	460,858	241,585
	Season II (March-June)	468,539	245,611
Aloma	Season I (March-June)	613,053	223,149

Where, NSIR- Net scheme irrigation requirement

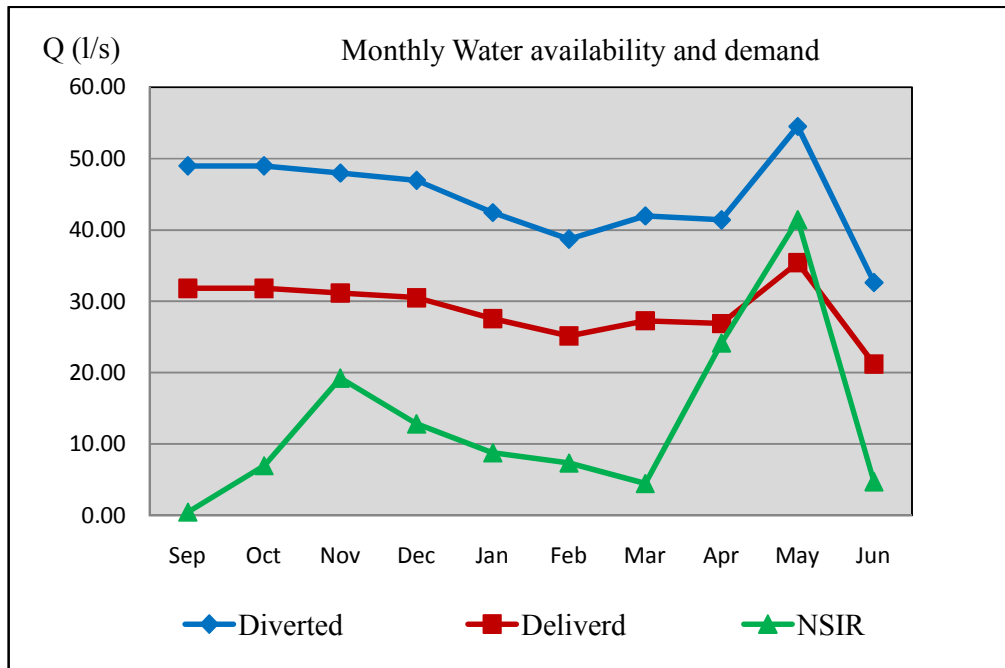


Figure 4.6: Water availability and demand of Jari SSI scheme

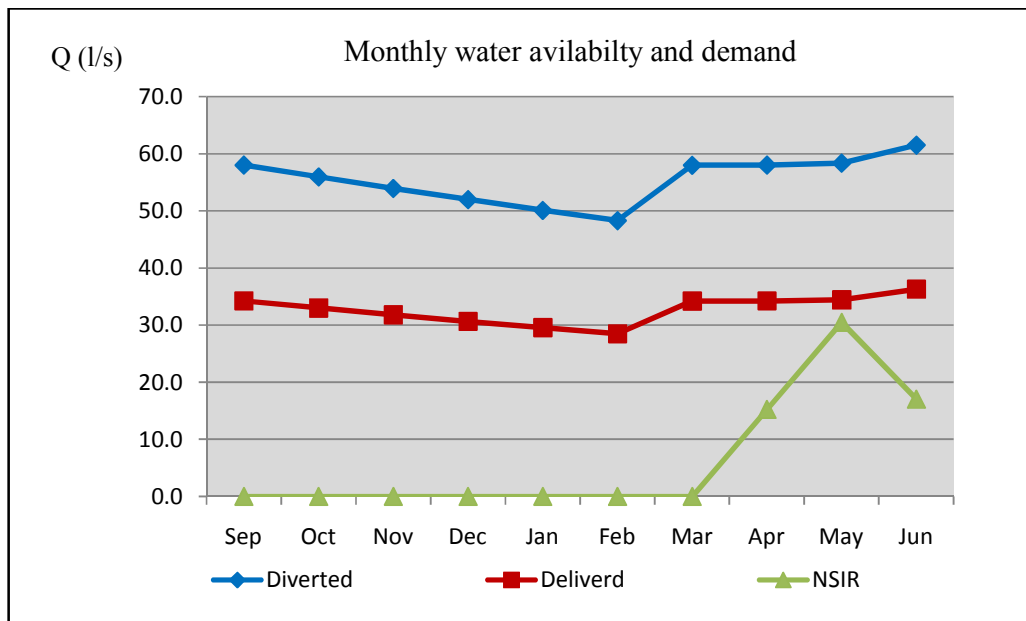


Figure 4.7: Water availability and demand of Jari SSI scheme

4.10. Irrigation Scheduling

Water application depth and interval in days are the important elements in irrigation scheduling. However, there was a problem in irrigation schemes applying the required depth of water at the proper time to optimize crop yield. The irrigation interval in Jari SSI scheme is rigid rotational schedule, the average cycle length is 15 days. The irrigation

interval was similar for different crops. While in Aloma the rigidity is modified with the condition of plant and availability of water; the interval varies between 10-12days.

At present, the crops grown in the schemes suffer from moisture stress problems as a result yield of crops is reduced. Table 4.18 showed the irrigation intervals practiced by farmers. Moreover, it was difficult to grow crops that need frequent irrigations. Most of the time farmers grow chick pea by using residual moisture and only apply two times irrigation water at both schemes.

Volume of water applied during irrigation events was determined through multiplying the average flow rate by duration of flow in that particular event. Average depth of water entered into the farmers' field during irrigation events were determined by dividing volume of water applied by their respective area. Based on field measurements, mean irrigation water applied to the fields' were 33.29mm and 67.17mm per application in Jari and Aloma SSI schemes, respectively (Table 4.16). There was a problem in delivering irrigation water in the right amount (size, frequency, and duration).

Table 4.18: Irrigation interval practiced by farmers in Jari and Aloma irrigation schemes

Jari			Aloma		
Crop types	Irrigation interval (days)	Irrigation frequency	Crop types	Irrigation interval (days)	Irrigation frequency
Chick Pea	30	2	Teff	12	8
Maize	15	6	Wheat	12	8
Pepper	15	8	Potato	10	10
Teff	15	6	Chick Pea	30	2
Onion	15	6	Maize	10	8
Sugar Cane	30	11	-	-	-

Required irrigation interval and depth

Furthermore, irrigation schedule is very important to achieve the maximum crop yield and water productivity. As a result, it needs to fix the most suitable and practicable interval which is constant at each growth stages. Scheduling at farmers fields should consider fixed interval and fixed water depth application techniques at the different growing stages, because farmers are not in a position to measure and monitor the moisture contents of the soil prior to irrigation event.

Additionally, plant water requirement is highly dependent and varies on the growing stages, i.e. plant water demand at initial stage is not equal to the plant water demand at

development stage. As a result it is better grouped the depth and interval based on growing stages. Furthermore, it helps to minimize the confusion gaps of farmers on irrigation scheduling.

The total available water (TAW), the difference between field capacity and wilting point of the soil in the root zone, was computed using Eq. [2.1]. To avoid crop water stress, irrigation should be applied before or at the moment when the readily available soil water is depleted. To avoid deep percolation losses that may leach nutrients out of the root zone, the net irrigation depth should be smaller than or equal to the root zone depletion (Allen *et al.*, 1998). By using Equations [2.2] and [2.3] consequently irrigation intervals of the main crops were determined (Table 4.19). Thus, in this study the depth of irrigation water (D) and schedules were computed through CROPWAT 8.0 for the listed crops in table 4.19. The detailed irrigation schedules of chick pea and onion in Jari, and teff and potato in Aloma irrigation schemes were indicated in appendix table from 20-27.

Table 4.19: Computed irrigation intervals at each growth stage and irrigation frequencies

Crops	Jari SSI scheme					Aloma SSI scheme				
	Growth stages (Irrigation interval)					Growth stages (Irrigation interval)				
	I	D	M	L	Frequency	I	D	M	L	Frequency
Chick pea	16	16	14	30	5	20	13	9	20	7
Maize	8*	7	7	20	10	6	8	8	15	12
Pepper	3*	6	8	13	18	-	-	-	-	-
Teff	5	7	7	10	14	4	8	7	9	10
Onion	2	4	4	5	22	-	-	-	-	-
Sugar cane	16	16	16	22	16	-	-	-	-	-
Wheat	-	-	-	-	-	8	9	16	25	8
Potato	-	-	-	-	-	6	8	14	17	12

*crops grown in irrigation season I; I= initial; D= Development; M= Mid; L= Late stages

The existed irrigation interval of pepper and onion were far different from the required irrigation interval at Jari SSI scheme. Both crops required frequent irrigation with low application depths but the existed practice was long irrigation interval with relatively large application depth. This showed that the farmers were applying water in long interval throughout the growing stages.

Thus, this situation created a problem of over irrigation (deep percolation loss) at initial and development stage, and under irrigated during mid and late growing stages (water stress). The reason is that, water uptake capacity of the crop is directly related to the root

development and vegetative development stages. Consequently it leads to low water productivity and low crop production results.

Additionally the length of irrigation interval was small in the first two growth stages and became long as the growth stage increased (Table 4.19). A number of irrigation frequencies required or determined was greater than from farmers existed irrigation frequencies. As a result, it is better to scheduling growing crops with pre-determined cropping arrangements; to achieve better irrigation water management and crop production.

4.11. Estimation of Total Output Production

A total output production value was computed from two production seasons for Jari and from one production season for Aloma SSI scheme.

Table 4.20: Crop yields and output production values for Jari SSI scheme

Crop	Season I						Season II					
	Area (ha)	Yield (Q/ha)	Yield (Q)	Av. price (birr/Q)	Total income (birr)	Total income US \$	Area (ha)	Yield (Q/ha)	Yield (Q)	Av. price (birr/Q)	Total income (birr)	Total income US \$
	(1)	(2)	(3)=(1)*(2)	(4)	(5)=(3)*(4)	(6)=(5)/(20ETB)	(1)	(2)	(3)=(1)*(2)	(4)	(5)=(3)*(4)	(6)=(5)/(20ETB)
Chick pea	33.7	25	842	1000	841500	42075	-	-	-	-	-	-
Maize	27.5	45	1239	600	743580	37179	27.6	45	1242	600	745200	37260
Pepper	20.4	15	306	1100	336600	16830	11.5	15	173	1100	189750	9488
Mango	5.1	125	638	1200	765000	38250	5.1	-	-	-	-	-
Avocado	3.1	125	383	1200	459000	22950	3.0	-	-	-	-	-
Orange	4.6	115	528	1100	580635	29032	4.3	-	-	-	-	-
Banana	2.6	120	306	1000	306000	15300	2.1	-	-	-	-	-
Sugar Cane	5.1	1000	5100	150	765000	38250	-	-	-	-	-	-
Teff	-	-	-	-	-	-	40.3	13	523	1700	889525	44476
Tomato	-	-	-	-	-	-	4.9	195	953	717	683346	34167
Onion	-	-	-	-	-	-	5.8	160	920	1100	1012000	50600
Cabbage	-	-	-	-	-	-	4.6	102	469	733	343,924	17,196
Sub-total	102				4,797,315	239,866	94.6				3,863,744	193,187
Grand total= Season I+ Season II											8,661,059	433,053

Table 4.21: Crop yields and output production values for Aloma SSI scheme

Crops	Season II					
	Area (ha)	Yield (Q/ha)	Yield (Q/)	Av. price (birr/Q/)	Total income (birr)	Total income US\$
	(1)	(2)	(3)=(1)*(2)	(4)	(5)=(3)*(4)	(6)=(5)/(20birr)#
Teff	32.4	15	486	1700	826200	41310
Wheat	36	25	900	700	630000	31500
Potato	5.85	160	936	650	608400	30420
Maize	8.1	45	365	600	218700	10935
Chick pea	5.4	25	135	1000	135000	6750
Haricot bean	2.25	20	45	500	22500	1125
Total	90				2,440,800	122,040

#1US\$=20ETH birr, average currency exchange rate for 2014/15 production year.

4.12. Comparison of the Two Small Scale Irrigation Schemes

4.12.1. Water delivery indicators

Transporting the diverted water to the location of use, i.e. to the cropped field, is the main purpose of water delivery systems. In the course of this transport there are different losses that reduce the amount of water reached to the farm plot. The conveyance efficiency and water losses were calculated based on equation [3.6] and [3.7].

4.12.1.1. Conveyance efficiency

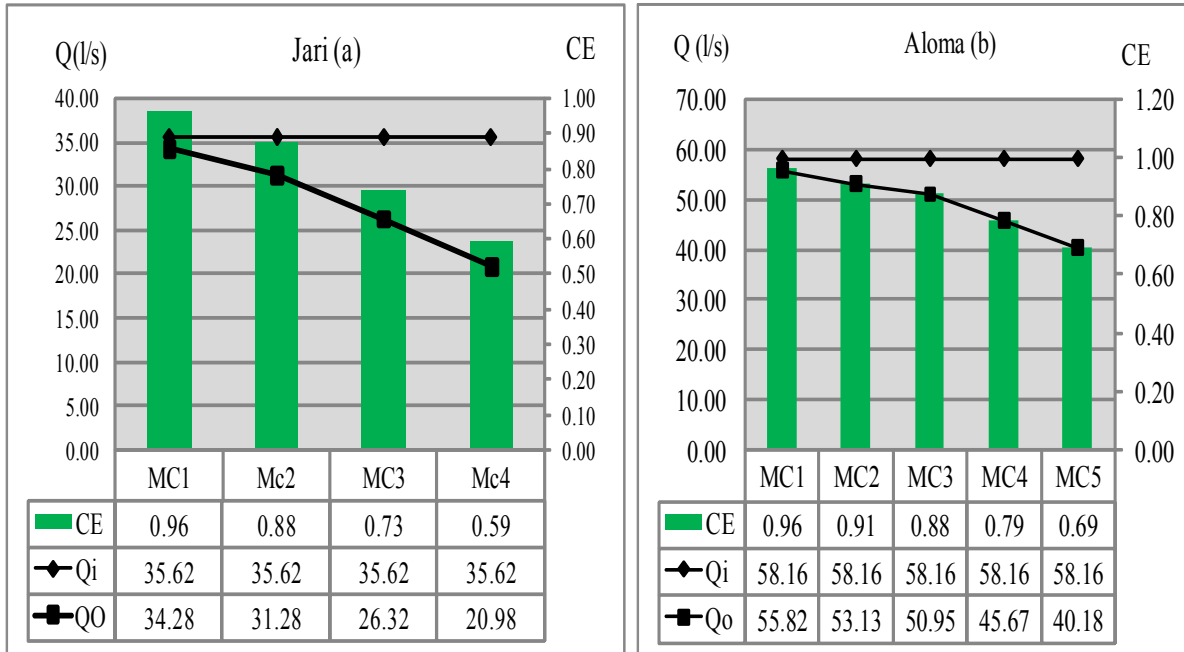
1. In the main canal

In Jari SSI scheme the conveyance efficiency of the main canal was decreases as far from the water source; from head to tail of the scheme. The mean observed conveyance efficiency ranges from 59-96%, the minimum one occurred at the tail / before branched to secondary canal four. The overall mean conveyance efficiency of the main canal was 79%. The conveyance efficiency of Aloma's scheme also ranges from 69-96%, the mean reached to 85%.

As observed in figure 4.8; the lost amounts showed an increasing trend, with spatial variations in both schemes, from head to tail of the scheme. The mean conveyance loss, in Jari $0.016 \text{ l s}^{-1}/\text{m}$ was higher than, in Aloma $0.011 \text{ l s}^{-1}/\text{m}$. Despite the computed values, as observed during filed assessment the situation seams the reveres; because the main canal structure of Jari's SSI scheme was relatively good than Aloma's. Moreover in Aloma; seepage and logging on earthen canal of 200m length, flumes leakage and underflow losses contributed for the high losses (Appendix figure 7 and 8).

Generally canal conveyance efficiency is affected by different canal attributes, which are canal types and flow rate amounts. These results were much lower than similar research findings in Ethiopia; Sisay et al. (2009) reported about $2.58 \text{ l s}^{-1}/100\text{m}$ water loss from lined main canal of average 43.21 l s^{-1} flow rate capacity in Blue Nile. However comparable result of average conveyance water loses $0.014 \text{ l s}^{-1}/\text{m}$ was obtained from lined main canal of 22.95 l/s average flow rate in South Wollo Zone (Menelik, 2008).

In spite of common losses; seepage and evaporation; none functional flow control gates, unauthorized water turnouts (breaching of main canals that leads leakage) and illegal water abstractions contributed for high water losses or low conveyance efficiencies at both irrigation schemes.



Where; Q_i =inflow, Q_o =outflow, CE=conveyance efficiency

Figure 4.8: Mean inflow, outflow and CE at the main canal in Jari and Aloma

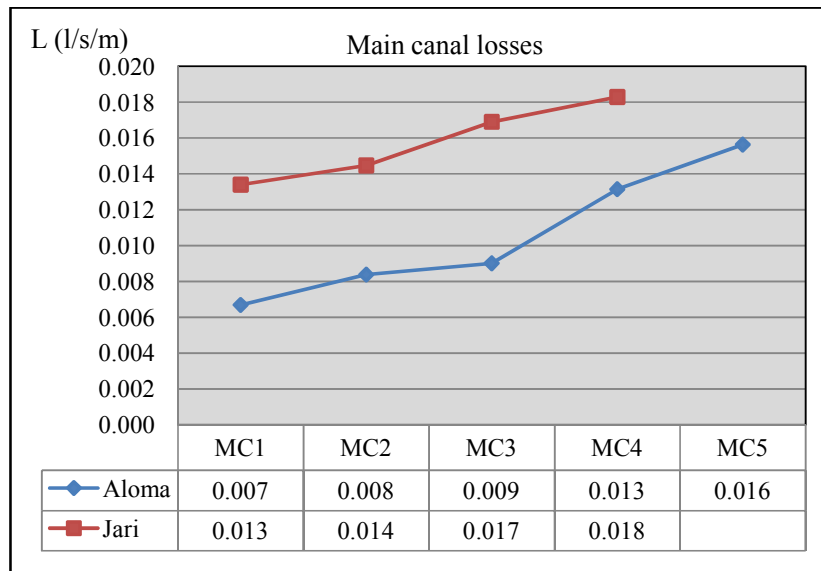


Figure 4.9: Mean water losses at the main canal of Jari and Aloma irrigation schemes

The major causes of low efficiencies in Jari relative to Aloma were water abstractions at the head and partial functionality of water flow control gates. This inefficient conveyance affected the equity of water distribution throughout the systems; particularly the tail users did not get their equitable share within the required time.

2. In secondary canal

As indicated in appendix table 14, from 16 observations, the minimum and maximum conveyance efficiencies of 76% and 95% were calculated in secondary canals of Jari irrigation scheme and the overall mean reached to 87%. This described that, an average of $0.71 \text{ l s}^{-1}/100\text{m}$, which 2.56% of the average flow rate in the secondary canal was lost per 100m length of canal. In the case of Aloma SSI scheme the conveyance efficiency became lower and the lost amount was higher than Jari SSI. The average conveyance efficiency of the secondary canal was 79%.

In Aloma the minimum and maximum amount of $1.61 \text{ l s}^{-1}/100\text{m}$ and $3.13 \text{ l s}^{-1}/100\text{m}$ were lost respectively (Appendix table 15). The largest amount of loss occurred at Secondary canal 5 relative to secondary canal 3. Secondary canal 5 was highly cracked and broken, which has been contributed for deep percolation and underflow losses.

In this scheme the lost amounts per 100m length was so high, but it was observable and actual at field conditions (Figure 4.10). From this an average loss of $2.4 \text{ l s}^{-1}/100\text{m}$ was computed from 10 observations in the secondary canals; which account 5.87% loss per 100m from the average flow rate in the secondary canal.

Generally the computed amounts of losses at both irrigation schemes were none comparable, which were higher than research findings reported in other parts of the world. Bakry and Awad (1997) reported 0.17 to 0.70% per 100 m canal losses in Egypt for canal capacity of 2000 to 12100 l s^{-1} . Akkuzu *et al.* (2007) also reported about 1.1% average loss from lined secondary canals of small scale irrigation scheme in Turkey at 30 l s^{-1} flow capacity.



Figure 4.10: Cracked and fractured secondary canals at Aloma



Figure 4.11: Secondary canals (silted, buried and over topped) at Jari SSI

However the result found in Jari was smaller than similar research results of small scale irrigation schemes in Ethiopia. Sisay *et al.* (2009) reported $1.59 \text{ l s}^{-1}/100\text{m}$, constitute 4% of the average flow rate 33.03 l/s . On the other hand the value computed from Aloma SSI scheme was much higher than the above research finding.

From this, the two irrigation schemes secondary canal conveyance efficiencies were much lower than the required amounts, but the problem was vast in Aloma SSI scheme. As a result the secondary canals of the two irrigation schemes have been found under poor performance conditions; couldn't deliver the amount of inflow rate to the required place. Furthermore, at both irrigation schemes the losses at secondary canals were higher than the main canal.

In general at Aloma SSI the major constraints for higher conveyance losses were;

- It was not constructed properly,
- Canals have been silted with weeds and soils,
- Canals were crack and broken,
- The canals had small cross sectional area that leads to over flow,
- Sides and beds have been greatly damaged by scouring water due to steep bed slope and drop structures.
- It has no any flow controlling structures.

While the main reasons for low conveyance efficiency at Jari scheme; specifically at the middle of the scheme (secondary canal 3); was siltation problems and covered by weeds. Figure 4.11 would be a good testimony for the current conditions of the secondary canals.

As illustrated in table 4.16 the amount of mean inflow rates at field canals/farm inlets were 16.32 l/s and 21.17 l/s at Jari and Aloma irrigation schemes, respectively. From the overall delivery efficiency; in average only 66 and 59% of the diverted amount of water were delivered to farm inlets at Jari and Aloma SSI schemes, respectively. Even though, the delivery efficiency at Jari was relatively higher than Aloma; both schemes had very low delivery efficiencies and high conveyance losses compare with lined masonry canal conveyance efficiency. Generally 34% and 41% of the diverted water at Jari and Aloma irrigation schemes was lost before it reaches to the farm plots.

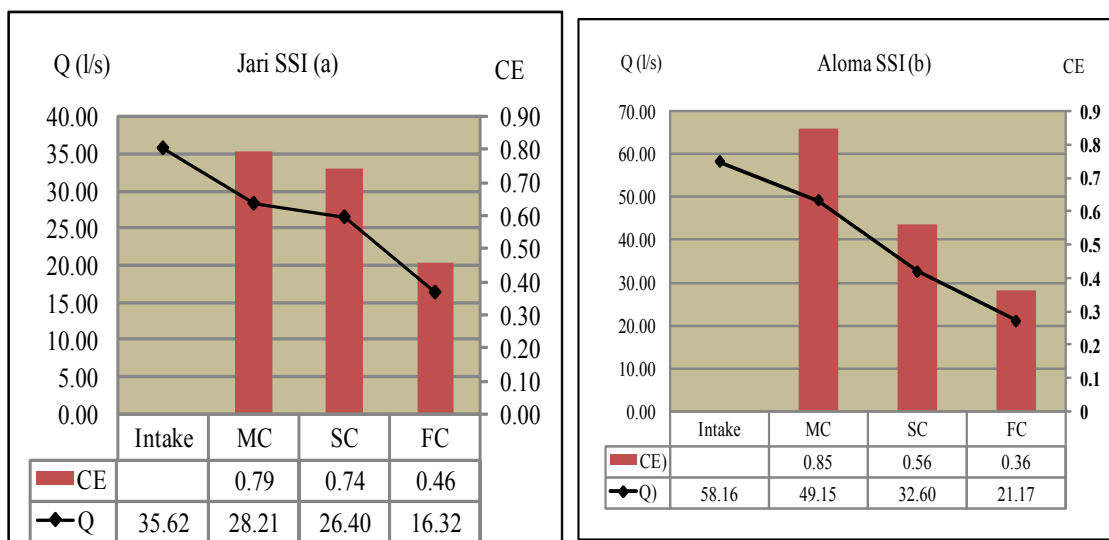


Figure 4.12: Over all water delivery conveyance efficiency at Jari and Aloma

The conveyance efficiency of tertiary canal is lower than the efficiencies of the main and secondary canals. The main reasons in Jari SSI scheme were seepages and over flow in unlined tertiary canal, and seepages due to high siltation by soil and weeds in lined tertiary canals. In Aloma there is no any defined tertiary canals, however there was a flow variation between flow rates in the secondary canals and farm inlets. This was highly related to the way of diversion of water from the secondary canal to farm plots. There were some difficulties to divert the coming flow from secondary canal to farm plot; due to high bed slope of secondary canal and local flow control methods.

4.12.1.2. Relative water supply

Based on equation [3.8], the indicator was determined for both schemes. In addition to delivered irrigation amount; total crop water demand, effective rain fall and crop irrigation demand were determined by CROPWAT model for a given cropping pattern and irrigation seasons (Table 4.11).

Relative Water Supply (RWS) showed the availability of water in relation to crop water demand. If the value greater than one which means the total water applied met the crop needs. Likewise, a value of RWS less than one may not represent a problem; rather it may provide an indication that farmers are practicing deficit irrigation with short water supply to maximize returns on water.

As observed in figure 4.13; RWS values in Jari and Aloma were 1.0 and 1.1, which indicated that the supplied water was sufficient for the crop water demand, i.e. neither surplus nor deficit. This implied that the supplied water was sufficient for crop water demand for the irrigated land. However, it couldn't irrigate additional farm land with this delivery amounts and available effective rainfalls. Furthermore, the result was supportive and could answer, why around 40% of the designed irrigable area became out off production in Aloma.

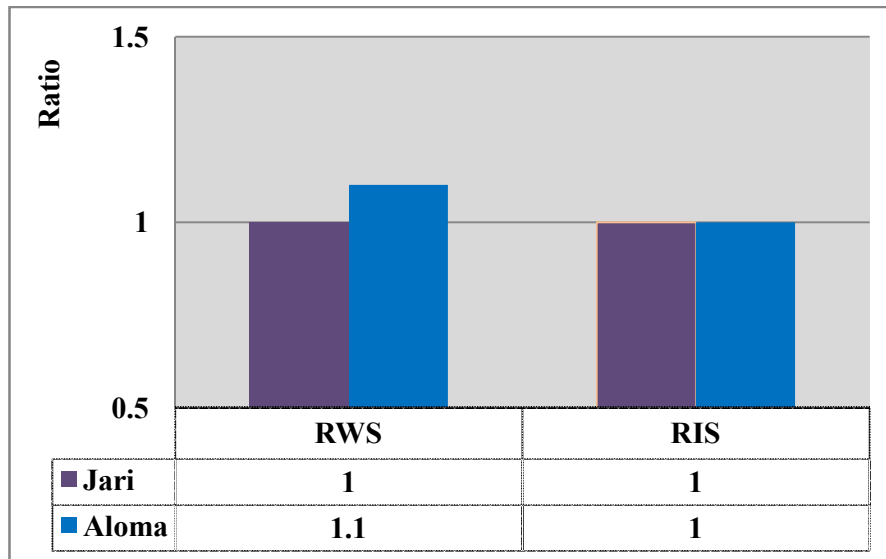


Figure 4.13: RWS and RIS indicators

4.12.1.3. Relative irrigation supply

Relative Irrigation Supply (RIS) indicator measures the proportional sufficiency of applied irrigation amount to the crop irrigation demand. The interpretation of the computed value is similar to RWS. At both irrigation schemes the computed values of RIS were almost one; which showed supplied irrigation was sufficient for crop irrigation demand. Molden *et al.* (1989) reported that, it is better to have a relative irrigation supply near one than a higher value. The lower value of RIS obtained due to the contribution of effective rainfall for crop water demand during the irrigation seasons.

Furthermore, the result confirmed that there has been water shortage to irrigate additional irrigable land. This situation might be happened with different reasons such as; a high monthly water flow variation; due to farmer's diversion at the head and the released amounts from the upstream users. This leads to the inadequacy of the amount of diverted irrigation water to satisfy the irrigation demand of the whole irrigable area.

Figure 4.6 indicated that the amount of diverted water was more than enough to irrigate the irrigable area in Jari SSI scheme; but due to low delivery performance efficiency, 34% of the diverted water was wasted before reaches to the farm plots. According to the current cropping pattern practiced by farmers and irrigated area in the irrigation season, the available water was enough from September to early March.

However the delivered amount became deficit starting from late March to early June. Particularly at months of November and May the water demand at scheme level shoot up reaches to peak. These two months were the critical periods, the first and the second irrigation seasons, which high water computations were occurred. Specifically in May the water demand was beyond the delivered one, 92% (115ha) of the irrigable area was covered by crops and had a water deficit of 5.98l/s. This situation showed the staggering of cropping pattern was highly concentrated in these two months (Figure 4.6).

As indicated appendix figure 6, it was observable that some crops were under water stress in the second irrigation season; due to water shortage and rigid rotational irrigation schedule. With proper cropping arrangements with irrigation scheduling, improved delivery and utilization techniques, the available water can irrigate additional land beyond the currently irrigated area.

In Aloma scheme the cropping pattern arrangement was concentrated in the four months only (March to June); the peak irrigation demand existed at months of late April to early June. Despite the low delivery efficiency performance of the system, the delivered amount was enough for the whole months. However, the area irrigated was 78% from the irrigable area currently demarcated (115ha), while the previous was 190ha. Furthermore starting from September, after the cessation of main rainy season to late February the available water was usually lost without giving any service (Figure 4.7).

Thus the diverted amount at head work needs to be increased by raised the water level and by improved the diversion techniques. Additionally carrying out of compressive water management activities to deliver the required amount of irrigation water safely to the command area is very essential.

4.12.2. On-farm water management indicators

4.12.2.1. Agricultural output indicators

Under this comparison land and water productivity levels and major constraints were analyzed. As indicated in table 4.20 and table 4.21 the output production values were estimated from the irrigation seasons of 2014/15 production year. The output per cropped area shows the response of each cropped area on generating gross return within the available water; the capacity of land productivity. While the output per unit water consumed describes the outcome gained through using a meter cube (1m³) of applied water; the capacity of water productivity.

Through using equations [3.10], [3.11], [3.12], [3.13] and [3.14]; the agricultural output indicators of Output per Unit Irrigated Area (OPUIA), Output per Unit Command Area (OPUCA), Output per Unit Irrigation Water Diverted (OPUIS), Output per Unit Irrigation Water delivered (OPUID) and Output per Unit Water Consumed (OPUWC) were computed, respectively. The basic parameters for the computation of these indicators have been listed in table 4.22.

Table 4.22: Parameters for agricultural performance indicators

Scheme	Command irrigable area (ha)	Area harvested (ha)	Production value (\$)	Irrigation water diverted (m ³)	Irrigation water delivered (m ³)	Crop water consumed (m ³)
Jari	125	197	433,053	929,396	487,196	886,671
Aloma	115	90	122,040	613,053	223,149	411,654

1. Land productivity indicators

Under land productivity issues output per unit area irrigated and output per unit command area performance indicators were analyzed for each irrigation scheme. Even though, there was a slight difference in irrigable area between the two schemes, the total production value obtained from Jari was 3.5 times higher than Aloma's irrigation scheme. As observed in figure 4.14; output per unit irrigated area values of 2,198 \$/ha and 1,356 \$/ha, were obtained in Jari and Aloma irrigation schemes, respectively. There was a difference of 842 \$/ha, which was high value per unit area.

OPUIA value of Jari irrigation scheme was comparable with results obtained in Mexico (Salvatierra of surface and public wells) and in Turkey (Seyhan irrigation scheme); values of

2,117 and 2,167 \$/ha respectively (Molden *et al.*, 1998). In Ethiopia Bekele (2011) reported an average value of 2359.28 and 2071.20 \$/ha in Hora and Jalale SSI schemes respectively. Additionally 2500 \$/ha was obtained in Wedecha-Godino community managed irrigation schemes (Dejen *et al.*, 2012).

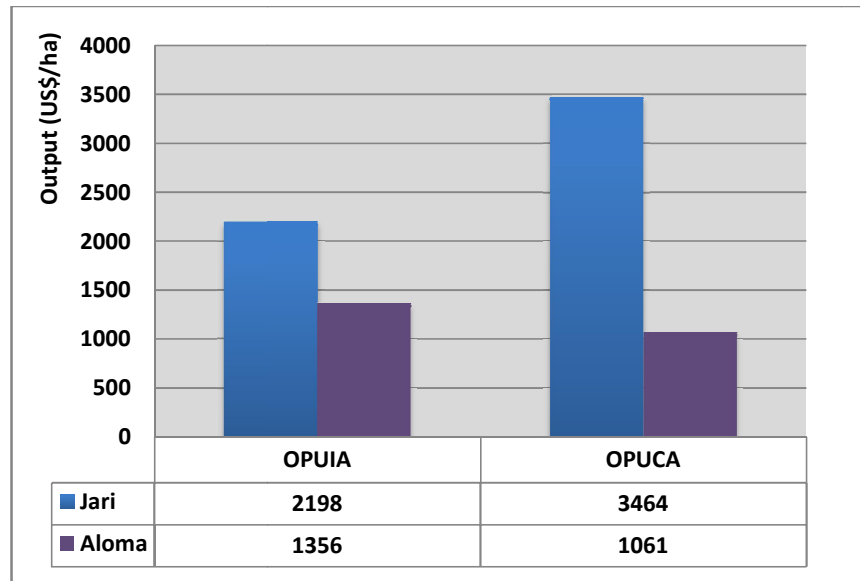


Figure 4.14: OPUIA and OPUCA (\$/ha) values at both irrigation schemes

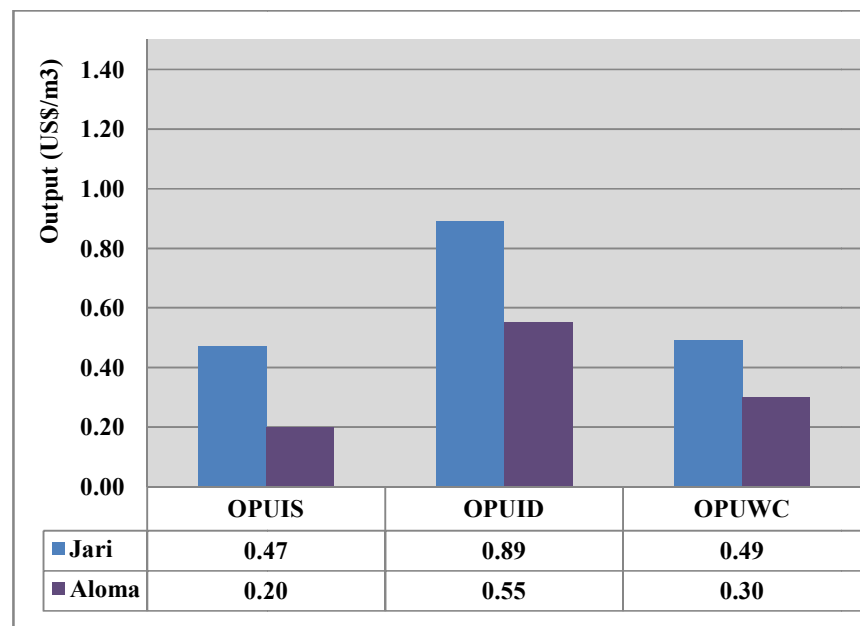


Figure 4.15: Computed values of OPUIS, OPUID and OPUWC (\$/m³) at both irrigation schemes

However the computed value was smaller than value of 3,085 \$/ha obtained in Burkina Faso, Savili irrigation scheme (Molden *et al.*, 1998). On the other hand the value obtained in Aloam was much lower than the above research findings. Thus this would be related to high value crop selection and crop productivity aspects. Even though the proportional area coverage of high value crops in Jari were less; i.e. vegetables/tomato, onion, pepper etc/, fruits/ avocado, mango, orange etc/; could gave larger value of outputs per unit irrigated area.

While in Aloma the main crops were cereals /Teff, wheat and maize/ and pulses which are less value and not usually recommended for irrigation, relative to horticultural crops. Therefore, their output value per unit irrigated area is very small. However, small irrigated area was covered by potato in Aloma. As observed during yield sampling period and showed remarkable yield from demonstration plots of integrated managements /fertilized and improved Variety/; carried out by LIVES project (Table 3.4). In Aloma SSI scheme farmers were not selecting high value crops /vegetable crops/. This resulted for low output per unit irrigated area.

As revealed in figure 4.14 the output per unit command area computed from Jari SSI scheme was three fold higher than Aloma. In Jari the output per unit command area was higher than, 57.8% increased, from the output per unit irrigated area. While in Aloma the situation was reversed; output per unit command area was lower than the output per unit irrigated area.

This implied that in Jari there was high irrigation intensities, i.e. twice in the irrigation season. But in Aloma there was one irrigation season. This depict that in Jari SSI scheme farmers are relatively having been used the land intensively than Aloma. Hence in Aloma irrigation scheme land productivity is the main constraint problem.

2. Water productivity indicators

Through using three indicators; water productivity performances were evaluated at both irrigation schemes; output per unit irrigation water supplied/diverted/, output per unit irrigation water delivered to the command area in the irrigation period and output per unit water consumed.

As indicated in figure 4.15 at both irrigation schemes the output per unit irrigation water delivered was higher than the output per unit water diverted and output per unit water consumed. This implied that the delivered amount of irrigation water was more productive

than relative to the diverted irrigation water and consumed water. Furthermore, output per unit consumed water was relatively more productive than the diverted amount of irrigation water.

In Jari from the total diverted water at the head, 47.2% was unproductive relative to the delivered amount; which means excess irrigation water was diverted to the command area with respect to delivered irrigation water. Likewise in Aloma 63.6% of the diverted water was unproductive. The output per unit irrigation water supplied of 0.47 \$/m³ and 0.2 \$/m³ were obtained from Jari and Aloma schemes, respectively. This revealed that a unit amount of diverted water was more productive, 135% higher in Jari than Aloma. With regard to Jari SSI scheme; comparable results were also investigated in different countries in the world; values of 0.37 and 0.38 \$/m³ in Burkinafaso and Malaysia respectively (Molden *et al.*, 1998).

The output per unit irrigation water delivered values of 0.89 \$/m³ and 0.55 \$/m³ were recorded in Jari and Aloma schemes, respectively. Even though the lower water delivery efficiency was a critical issue at both irrigation schemes, the output values of unit irrigation water delivered at farm inlet were better than other findings. Molden *et al.* (1998) reported that the output production value per cubic meter of irrigation water tends to be higher in regions where rainfall partially contributes for crop water demands in the irrigation seasons. But it depends on the ability of farmers and system managements to use rainfall effectively. At both irrigation schemes rainfall contributes about half of the total crop water demand but the variability of occurrence and distribution make less dependable.

Particularly OPUID of 0.89 \$/m³ values at Jari looks higher relative to other findings, because in this area rainfall contributed half of a crop water demand, and fruit trees require less frequent irrigation and it has been given high value of production. The output per unit irrigation water delivered results at Aloma scheme was similar with the research outputs of 0.55 \$/m³ at Godino community irrigation scheme in Ethiopia (Dejen *et al.*, 2012).

On the other hand, the outputs per unit consumed water values were lower than the output per unit delivered water by 44.9% and 45.5% at Jari and Aloma, respectively. The results revealed that in each scheme the actual crop water consumption was higher than the delivered irrigation water. The reasons behind was rainfall contributed to crop water demands during the irrigation season.

Generally the values of water productivity indicators computed from Jari SSI had shown higher performance. This implied there was better water management and crop selection experiences that leads to better water productivity functions. Despite the water delivery inefficiency, the water productivity values were satisfactory.

4.12.2.2. Fertilizer utilization efficiency indicators

Partial factor of productivity and agronomic efficiency indicators were selected for the comparison of fertilizer utilization efficiencies. For computation of the indicators crop yields and applied fertilizer rates are given in table 4.23.

Table 4.23: Crop yields, and nitrogen and phosphorus fertilizer rates at both schemes

Scheme	Crop type	Yield with fertilizer (kg/ha)	Yield without fertilizer (kg/ha)	N-fertilizer rate (kg/ha)*	P-fertilizer rate (kg/ha)*
Jari	Teff	1283	1238	32	23
Aloma	Potato	32550	21950	32	23
	Wheat	3743	2318	32	23
	Teff	2075	1419	32	23

*farmers use 50kg urea and 50kg DAP per ha.

1. Partial factor of productivity (PFP)

This indicator was computed based on equation [3.15]. Partial factor of productivity measures the comparison of a cropping system with its nutrient inputs, calculated in units of yield per unit fertilizer used.

At both irrigation schemes farmers have not been applied fertilizer amounts based on the recommended rates; instead they have applied a blanket /default/ rate of 50kg urea and 50kg DAP per ha for different crops. Despite low fertilizer applications in Aloma irrigation scheme, farmers believed that fertilizer could increase their yield amounts. But the situation is totally the reverse in Jari.

As observed in table 4.24; the partial factor of productivity for Teff crop was 40kg and 56kg of grain per unit kg of N and P, respectively. Drechsel *et al.* (2015) described the recommended ranges of PFP for cereal crops (maize, rice and wheat); i.e. 40-90 for N and 100-250 for P; lower levels suggest less responsive soils or over application of nutrients while higher levels suggest that nutrient supply is likely limiting productivity.

Table 4.24: Computed values of PFP and AE for N and P fertilizer rates

Scheme	Crop type	Partial factor of productivity at N-rate (PFP)	Partial factor of productivity at P-rate (PFP)	Agronomic Efficiency at N-rate (AE)	Agronomic Efficiency at P-rate (AE)
Jari	Teff	40	56	1.4	2
Aloma	Potato	1017	1415	331.3	461
	Wheat	117	163	44.5	62
	Teff	65	90	20.5	29

As a result the computed amount PFP for N rate was found in the lower ranges and the lowest one from the major World regions, but it is relatively comparable with Oceania region outputs of 40 kg N⁻¹ for N-rate of 48 kg ha⁻¹. On the other hand the computed PFP for P-rate was far below the specified ranges. Thus the low levels of PFP suggested that, the soil was less responsive for the applied nutrients for Teff crops at Jari irrigation scheme.

However, it needs to give attention for the generalized categorization of Teff crop under cereal crops; which the values were not specifically researched for Teff crop. Furthermore, this result has been agreed with farmer's idea; they have justified that fertilizer application have no contribution for Teff yield incensement. However the sampled soil laboratory results revealed that the irrigation scheme's organic matter (OM), total nitrogen (N) and available phosphorous (P) were rated as low, moderate and low, respectively. This indicates the soil is poor in nutrient contents. Hence for detailed recommendations, it needs detail study on fertilizer rates for different crops in the area.

Similarly, at Aloma irrigation scheme, partial factor of productivity values of 1017, 117 and 65 kg grain per unit kg N-fertilizer rate and 1415, 165 and 90 kg grain per unit kg P-fertilize rate were computed for potato, wheat and Teff crops in respective order. According to Drechsel *et al.* (2015) report partial factor of productivity values are vary among crops in different cropping systems, because crops differ in their nutrient and water needs. A comparison between crops and rotations is particularly difficult if it is based on biomass yields, since they differ in moisture contents (e.g. potato vs. cereals).

However it could gave insights for the impact of fertilizer on yield and the level of response for different crops. At Aloma for potato crop the applied fertilizer rates were less than as compared to the recommended rates. On other hand the calculated PFP for potato was high. This implied that low fertilizer application rate reduced potato crop yield.

Furthermore the sampled soil results indicated that the irrigation scheme's organic matter (OM), total nitrogen (N) and available phosphorous (P) contents were classified as low, moderate and low, respectively. Thus the soils were poor in organic content and available phosphorous.

For wheat crop the determined PFP for N-rate was higher than the specified ranges; which indicated that the less amount of added fertilizer rate limits wheat yields in the area. While for Teff crop the calculated PFP values laid in the specified ranges, which showed that the applied amount of fertilizer rates contribute for productivity. Thus in Aloma SSI scheme the applied fertilizer amounts can increase crop yields

2. Agronomic efficiency (AE)

Agronomic efficiencies of the selected crops have been calculated through equation [3.16] for both N and P fertilizer rates at each scheme. Drechsel *et al.* (2015) presents the recommended ranges of agronomic efficiency values in World bases, which are 15-30 kg grain per unit kg of N-fertilizer rate and 15-40 kg grain per unit kg of P-fertilizer rate. The lower levels suggest changes in management could increase crop increase or reduce input costs.

As indicated in table 4.24, AE values of 1.4 and 2 kg grain per unit kg of N and P fertilizer rates were recorded for Teff crops at Jari. The calculated value was far below from the World range and wasn't comparable with average results obtained in Africa for cereal crops of 21 kg grain per kg of N and P (Ladha et al., 2005). Therefore, the applied fertilizer rate couldn't boost up yield of Teff at Jari.

In Aloma for Potato crop the computed value was so large, due to fresh weight /high moisture content/, but the value indicated that there was a yield response for applied fertilizer amounts. However, low fertilizer application rate affects potato production levels at Aloam. For wheat crop 44.5 kg grain per unit kg of N and 62 kg grain per unit kg of P were obtained at Aloma. The calculated value was higher than the specified ranges.

Agronomic efficiencies of 20.5 kg grain per unit kg of N-rate and 29 kg grain per unit kg of P-rate were calculated for Teff crops at Aloma. The values were laid in the World recommended ranges. As a result the added amounts of fertilizers were contributed for maximum production of Teff in Aloma. Thus the added fertilizer amounts limit the yield increments of Potato and Wheat crops in Aloma SSI scheme. Generally in Aloma SSI

scheme, it needs to apply the recommended amounts of fertilizer rates to obtain maximum crop yields.

4.12.3. Physical performance indicators

Two basic physical indicators of irrigation ratio (IR) and sustainability of irrigated areas (SIA) were selected and computed, based on equations [3.17] and [3.18], to evaluate the status of both irrigation schemes. The result is depicted in table 4.25.

Table 4.25: Basic parameters and computed values of IR and SIA

Scheme	Initial irrigated area (ha)	Currently irrigable area (ha)	Area irrigated (ha)	IR (%)	SIA (%)
Jari	146	125	115	0.92	0.86
Aloma	190	115	90	0.78	0.61

Where IR- irrigation ratio, SIA-sustainability of irrigable area

4.12.3.1. Irrigation ratio

Irrigation ratio shows the level of utilization of a given irrigable area in the specific production season; but it slightly differs from irrigation intensities. In Jari high irrigation ratio of 0.92, which indicate 92% was irrigated from currently irrigable area; but the scheme had high irrigation intensities of 174% in the irrigation seasons, they produce twice in the irrigation season.

In this scheme, farmers were more interested to produce using irrigation because they could get better income by producing vegetable crops, fruits and maize / to get double benefit of grain yield plus feed for their livestock/. Additionally some farmers whose farms' were affected by runoff during long rainy seasons 'kiremit'; fallowed it and start sowing chick pea when the rainy season end in September by using residual moisture and they also grow other crops in the second irrigation season.

While in Aloma the situation was totally opposite, irrigation ratio of 0.78 relatively smaller than Jari. If we consider the irrigation intensities, it is under utilization. In this scheme single cropping system was common. The reasons behind were; farmers have negative attitude for irrigation development starting from construction period; they considered irrigation affects their land by 'depleting the soil nutrients'. Then after in the first production year, District Agricultural and Rural Development Office recommend them to produce carrot. Unfortunately they have not got good return due to market problem.

In this situation relatively Jari had a good achievement and need to share the experience to Aloma scheme. In Aloma scheme works must be done in integrated manner; starting from awareness creation to technologies utilization.

4.12.3.2. Sustainability of irrigated area

As observed in figure 4.16 the computed values of sustainability of irrigated area at both schemes were below one, which indicates the current irrigable area is below the irrigable area proposed during the construction period of the irrigation scheme. Even though the irrigable area in both schemes showed decreasing trend, the magnitude was so high in Aloma irrigation scheme; about 39% of originally planned irrigated area has not been irrigated. The main reasons farmers raised were water shortage; i.e. the design area is so large relative to the water source and quality problems of the construction materials and operation procedures.

Currently the hydraulic structures have been out of function, (i.e. cracking, sliding), specifically the secondary canals were highly damaged. Additionally farmers' attitude was another obstacle for the underutilization of the irrigable area. The scheme has been giving service for the last 3 years only, but its current condition is not good relative to its service years.

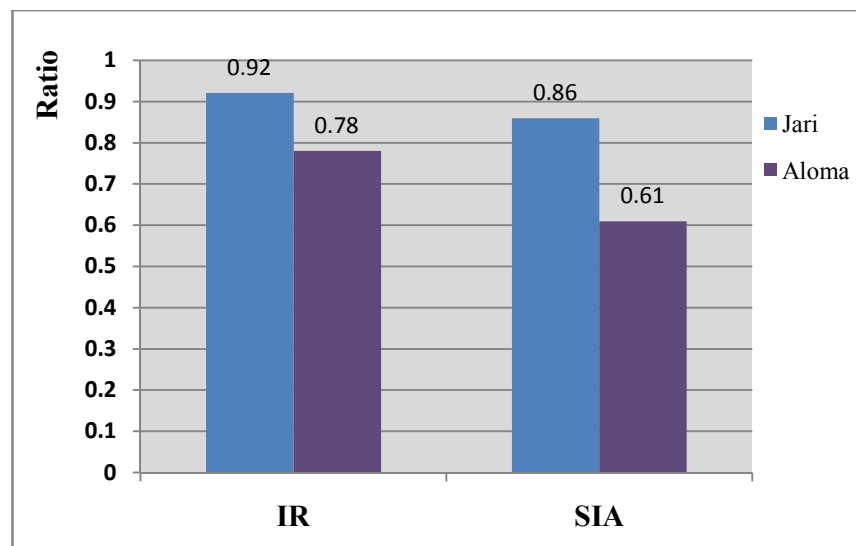


Figure 4.16: Irrigation ratio and sustainability of irrigated area at Jari and Aloma

Dejen *et al.* (2012) has got the maximum irrigated area reduction by 20% in Godino and Gohaworki irrigation schemes in Ethiopia. However the result obtained from Aloma

irrigation scheme was so large and not comparable. As a result through participatory approach undertaking a rehabilitation work is essential, particularly the secondary canals and the main canal (the earthen type around 200m length to change to lined masonry).

Likewise in Jari 14% of the original irrigable area has not been irrigated yet, it was damaged by over flooding of Mile river, it is found in the right side of the command area. Around 22ha of irrigable area that found in the river side was highly flooded, packed, and silted by sands and river boulders. Additionally in the left side direction from the command area; in Kezikaze River direction; the artificial cut of drain was broken out and at main rainy season the flood passes crossing the command area. As a result, during the main rainy season larger portion of the farm land in the command area was not cultivated (Appendix figure 10).

The regional government and District administrative office in collaboration, they have tried to reduce the problems by excavating the sediments using machine and by constructing check dams (Gabions). However, the problem was not yet solved. This could be since measures taken far were not implemented following an integrated watershed management approach.

4.12.4. Financial indicator

4.12.4.1. Gross return on investment

Due to lack of long term output production costs in the irrigation schemes, only 2014/15 production year gross value of production was used. And the costs of irrigation infrastructures were obtained from Agricultural and Rural Development Office, and from design documents. Under this estimation the cost of weir was excluded, only the cost of distribution system was considered.

For computation purposes the cost of irrigation infrastructure was estimated as Present Value of Worth, through the average interest rate of the service years. The base year taken to estimate the Net Present Worth was 2015, with a service years of 10 and 3 for Jari and Aloma schemes accordingly. Aloma irrigation scheme has diversion weir and Jari has a check Basin type. Based on equation [3.19], the values were computed and summarized in table 4.26.

The gross investment cost per hectare of each irrigation schemes were calculated for the actual irrigable area instead of the designed irrigable area. Because if we considered the designed irrigable area for the calculation of investment cost and the total productions were

calculated from the current actual irrigable area; finally it would lead a wrong conclusion. The result is given on table 4.26.

Table 4.26: Investment cost of the irrigation systems

Irrigation scheme	Irrigable area (ha)	N	Water delivery structures cost (birr)	Water delivery structures cost (birr/ha)	Cost in PNW (birr/ha)	Production cost (birr/ha)	GRI (%)
Jari	125	10	6,095,019*	48760	79,425	43,960	55
Aloma	115	3	5,625,000**	48913	56,625	27,120	48

PNW- Cost in Present Net Worth value (year), $F=P(1+i)^n$, i =interest rate (%), n = number of service year, p =initial construction cost, F = present net cost, *84.74% of the total construction cost including water harvesting ponds, GRI-gross return on investments. **80% of the total cost.

Gross return on investment values of 55% and 48% were obtained from Jari and Aloma SSI schemes respectively. The results revealed that Jari had higher gross return on investment than Aloma. The possible reasons for high gross return on investment in Jari, were grown of high value crops and high irrigation intensities/double cropping per irrigation season/.

The reason behind for the low GRI on Aloma's irrigation scheme were; smaller irrigated area, less irrigation intensity /one crop per irrigation season/ and grow low value crops i.e. cereals and pulses. Comparable results were investigated, 52% in India, 59% in Mexico, 64% in Niger and 43% in Sirilanka (Molden *et al.*, 1998). Even though the gross return on investment cost values were relatively good, but it requires improving the productivity of each scheme by applying recommended agronomic practices and growing high value crops.

Particularly in Aloma SSI, needs to focus on to utilize the available irrigable area effectively with appropriate water management techniques and change the existing cropping pattern towards high value crops with implementing appropriate technologies. While in Jari required to design appropriate cropping pattern with efficient water utilization techniques.

4.12.5. Organizational indicators

Organizational performance is an important indicator for the sustainability and productivity of irrigation systems. According to the policy frame work designed for SSI scheme development in Ethiopia; management and operation of SSI system is the joint responsibility of irrigation agency, cooperatives, district and 'kebele'⁶ level administrative, farmers and

⁶ Lower administrative level /village/

their organizations (MoWR, 2002). As a result, SSI schemes operation is managed by Water User Associations 'WUAs'.

Furthermore the new proclamation would have good impact for IWUA's legal enforcement power, decision making circumstances, administrative, management, and for better implementation of operation and maintenance issues.

4.12.5.1. Organizational structures of WUAs

After construction had been completed the government transferred the schemes to the community in a mode of joint management by both the government and the community, to carry out their respective responsibilities. The government has the responsibility for undertaking major maintenance or rehabilitation works which could be beyond the capacity of the user cooperatives /associations/. On the other hand, the operation and other minor maintenance activities are the responsibilities of the irrigation user cooperatives /associations/.

Nowadays the major management tasks of the water user association committees are; allocate water and controls water distribution, ensure the safety of the scheme through organizing operation and maintenance works, and mobilizing resources for these works and resolve disputes related to water and maintenances based on their bylaws. Based on the context of SSI schemes frame work; Jari's and Aloma's irrigation schemes WUAs were established after construction completed, during the first year implementation period of 2005 and 2013, respectively. From the respondents, 77.8% in Jari and 76.2% in Aloma were member of the WUAs.

In Jari SSI scheme the association was initially formed in cooperative forms as a multi functional local institution with three main objectives, which were operation and maintenance of the scheme, input and credit supply and marketing of out puts, but not functional yet. While in the case of Aloam WUA's objectives were water allocation, structural control, operation and maintenance activities; not extended for input and credit supply and marketing of outputs.

However, both parties have not been able to translate their responsibilities into reality on the ground. At present the association only has been trying to practice the water allocation issues with minimum achievements, but the gap was enormous in Aloma SSI scheme.

The WUAs at both irrigation schemes have developed their own management structures that suit for management of the irrigation schemes. Woldeab (2003) stated that one of the social requirements for successful irrigation is organization and management structure that suit the irrigation infrastructure.

Generally the WUAs have executive committee, sub-committee and water user teams for better accomplishment of operation and maintenance activities at irrigation system and distribution levels. An Executive Committee consisting of seven members in each irrigation system is responsible for operation and maintenance of the irrigation systems. The composition of the WUA committee members has, chairman and vice chairman, a secretary, control and monitoring committee, cashier and two members.

The general assembly is the highest body in which all members of the irrigation systems collectively discuss the highest level issues and make the final decisions based on the bylaw. Water allocation and arrangement of irrigation schedules are the responsibility of the general assembly. Controlling and monitoring committee which supervises and controls the implementation process, and determines whether it is in line with the direction given by the general assembly and with the stated bylaws. The bylaw was developed by the initiation of Agricultural and Rural Development Office with the main objective to sustain the irrigation infrastructure and to assure fair distribution of water among beneficiaries

Organizational set up and management functions of the committees are further decentralized depending on layout of the schemes. All water users in the irrigation systems constitute the water users teams (WUTs) 'Ketena⁷', contains a number of water user groups 'Yewuha Budin'. Sub-committees are in charge of control of water distribution and coordination of maintenance activities in the respective territory units, water user teams. As a rule, they are accountable to the executive committee and expected to report to the board when regulations in the water distribution by-laws are violated. However, they did not effectively discharge this responsibility as stipulated in the bylaws, because of organizational weakness.

Generally Jari SSI scheme has 6 WUTs and 12 WUGs; which each WUG contains 30-48 users. While Aloma has 3 WUTs, 7 WUGs and each WUG contain 25-35 users.

⁷ Local water management organizational level

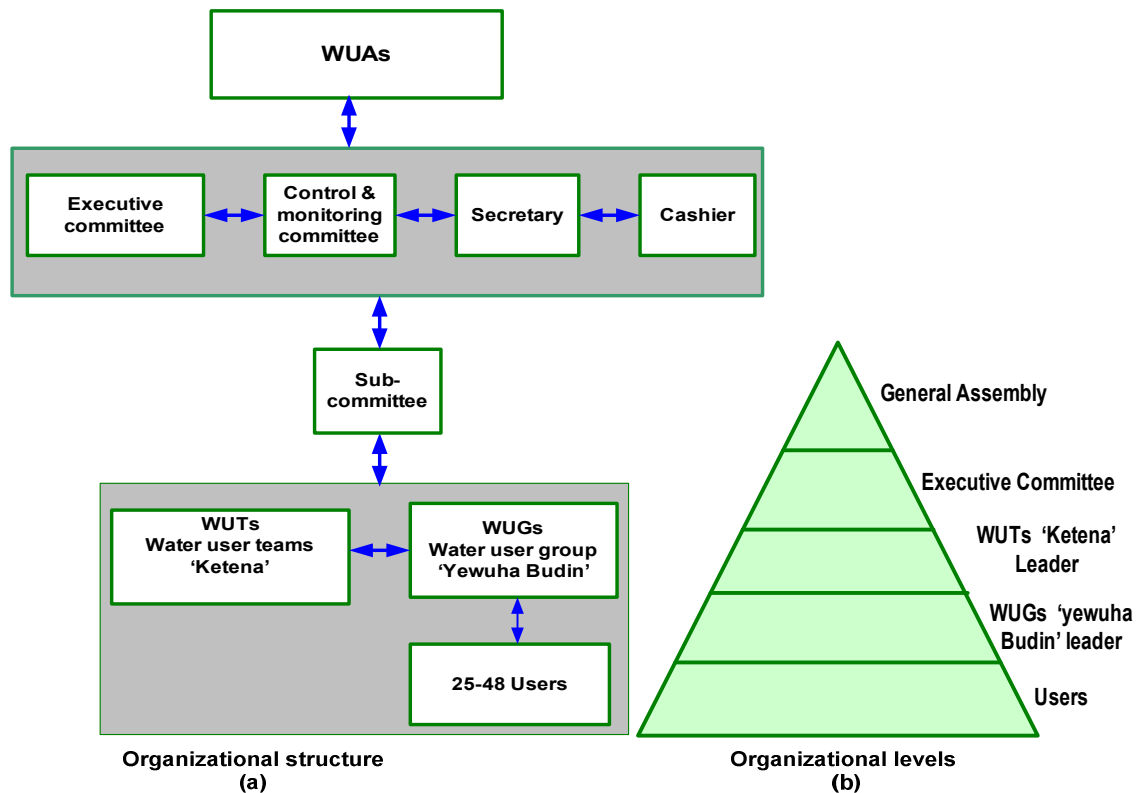


Figure 4.17: WUAs organizational structure and organizational levels

From the respondents 88.9% in Jari and 95.2% in Aloma believed that WUAs had a positive contribution for smooth functionality and sustainability of the irrigation schemes. However the WUA was not fully functional as they expected. Organizational management and operation was a critical problem at both irrigation schemes. Thus needs to strengthen the capacity of WUAs through giving up to date training and, make monitoring and evaluation of their status with correction measures. Furthermore in Aloma needs restructuring WUAs committees.

4.12.5.2. Bylaws

Effective and sustainable management of SSI scheme requires well-established internal bylaws which contains detailed rules and regulations developed and approved by beneficiaries, which ensure the interest of all irrigators. Despite the implementation gaps, a WUA in Jari has relatively better written and defined bylaws compared to Aloma.

Jari WUA's bylaw was established after 5 years of implementation. Establishment gap created problem on the productivity and sustainability of the scheme. Mean while Alom's WUA was established in 2013, the organization has a bylaw, but it is not written and detailed. Most of the time, beneficiaries had been ruled by their religious rules.

Due to the poor functionality of WUAs at organizational levels and reluctance of committee members, rules written in the bylaws have not yet fully implemented. Offenders who were found guilty of turn abuses, breaching canals, power abuse to use water out of their turn and failure to respect decisions of the WUA committee members have not been fully charged. In Jari SSI there was high illegal water abstractions and breaching of canals, but none of them were charged in accordance with the bylaw. Illegal water users contributed for unfair water distribution systems at both SSI schemes. Additionally during group discussion, the water user association committees confirmed that they had not been got any information and awareness about the new IWUAs declarations yet.

4.12.5.3. Fee collection

In Jari SSI the bylaw defined the amount of water use fees for maintenance works. According to the bylaw the water use fee would be estimated based on a standardized farm plot area of (20m*40m=800m²); for this area 20ETB for members and 30ETB for non members; and the fee round would be paid in each irrigation season.

However, the WUA committee was collecting the fee through simple judgment without measuring the size of irrigated farm land of the household and it also varied from farmers to farmers. Furthermore, they were not collecting the water use fee using legal receipts; the system seems highly corrupted. In Aloma SSI scheme, 60ETB for membership fee was only collected, when the WUA was established.

Generally at both SSI schemes there were lack of transparency in ways of collecting fees; it was not in accordance with legal financial systems; the process was exposed for corruption. Additionally the situations slow down the motivation of farmer's participations in operation and maintenance activities. As a result it is required to put standardized way of fee collection mechanism and preparing legal receipts for any payment.

4.12.5.4. Degree of participations of users in operation and maintenance

Participating users during planning and construction period had a positive contribution to create sense of ownership and to assure sustainability. However the key informant interviewed result revealed that the beneficiaries were not participated both at planning and construction stages in both irrigation schemes. The effect of not participating beneficiaries was clearly visible in Aloma SSI scheme. Farmers were not aware about the importance of irrigation development for the area. As a result, beneficiaries were not interested to efficiently use the irrigation infrastructure constructed to them.

Even though the government gave the operation and other minor maintenance responsibilities to users, they didn't carry out any operation and maintenance activities at both schemes yet. However, beneficiaries annually clean canals by removing sediments and weeds in scattered manner.

Participation varied between the two irrigation schemes and between beneficiaries in the same scheme. Most of the time farmers prefer to clean the nearby canals from their farm plots. According to the bylaw in Jari irrigation scheme beneficiaries were expected to maintain twice per year in September and February. However, 77.8% of the respondents were participated once in the production season. The beneficiary's response on maintenance condition of the irrigation infrastructure was varied in Jari SSI scheme; the reflection depends on their farm plot proximity to the infrastructure. While in Aloma 61.9% the respondents justified that the infrastructure has been under bad conditions.

Table 4.27: Perceptions of respondents on the maintenance condition of irrigation infrastructures

Maintenance conditions	Jari		Aloma	
	Frequency	Percent	Frequency	Percent
Good	6	22.2	1	4.8
Medium	9	33.3	5	23.8
Bad	10	37.0	13	61.9
Very bad	2	7.4	2	9.5
Total	27	100.0	21	100.0

Data source; HH field survey

In Jari the major structural failures has been in the cutoff drain and drainage structures; which leads huge flooding impacts on farm plots. It requires well designed maintenance works for improvement of the cut off drain and drainage structures. From the respondents in Aloam, 76.2% beneficiaries observed structural failure in canals, specifically in secondary canals.

Table 4.28: Respondent’s observation on location of structural failure

Location	Jari		Aloma	
	Frequency	Percent	Frequency	Percent
The head work	1	3.7	-	-
The canal	9	33.3	16	76.2
Other structures	17	63.0	5	23.8
Total	27	100.0	21	100.0

Data source; field survey

4.12.5.5. Water allocation and water distributions

In Jari SSI scheme, water allocation was rigid rotational program in water team ‘ketena’ level but for individuals it was according to spatial sequence of turns (the lands below each turn-out are fed out one after the other). The amount of time allowed for each field depends on farm plot areas. It did not considered the crop types and their crop water requirements, and monthly flow amount in the canal. The WUA committees prepare the schedule by guess without any technical support from DAs or district irrigation experts.

Similarly in Aloma water was allocated based on farm plot area at ‘ketena’ level, but the only difference was if farmers needs water could access at any time upon request. But the technical problem in water allocation was like Jari.

Respondents stated that the main scheduling criteria in ranks (1st, 2nd and 3rd) were, fixed time period, water supply availability and condition of the plant in Jari; and condition of the plant, fixed time period and water availability in Aloma , respectively (Table 4. 29). These situations create to some farmers over supplied with water, while others obtained water which was far short to meet their needs as water allocation has been made by guess. Consequently beneficiaries reported the presence of power abuse and selfishness, and accuse WUAs committees.

Table 4.29: Main criteria used to scheduling irrigation

Scheduling criteria	Jari			Aloma		
	Frequency	Percent	Rank	Frequency	Percent	Rank
Condition of the plant	2	7.4	3	14	66.7	1
Fixed time periods	18	66.7	1	4	19.0	2
Water supply availability	7	25.9	2	3	14.3	3
Total	27	100.0		21	100.0	

Data source; HHs field survey

Table 4.30: Levels of water distribution

Levels	Jari		Aloma	
	Frequency	Percent	Frequency	Percent
Very fair	-	-	4	19.0
Fair	17	63.0	13	61.9
Unfair	10	37.0	4	19.0
Total	27	100.0	21	100.0

Data source; HHs field survey

Table 4.31: Reasons for unfair distribution of water

Reasons	Jari		Aloma	
	Frequency	Percent	Frequency	percent
Head users	1	9.1	1	25.0
Corrupted officials/WUA/	2	18.2	-	-
Illegal water users	5	45.5	2	50.0
Non-reliability of the water sources	3	27.3	1	25.0
Total	11	100.0	4	100.0

Data source; HHs field survey

As a result water allocations and rigid rotational schedule, which was prepared and implemented by water user association committees, has got many limitations in design and implementations. In terms of design the allocation was made by guess. Amount and time of water supply were not defined in accordance with the water requirements of the different crops grown, but only depends on the individual plot areas. This creates a problem of implementation of fair water distribution.

4.12.5.6. Conflicts and conflict managements

Conflicts on irrigation water occur in many stages; among users in the irrigation system, between users and WUAs, and between downstream and upstream users. But at both irrigation schemes conflicts between upstream users and downstream users at different system levels was not as such a main problem.

Table 4.32: Beneficiaries response on conflict over irrigation water

	Jari		Aloma	
	Frequency	Percent	Frequency	Percent
Yes	16	59.3	9	42.9
No	11	40.7	12	57.1
Total	27	100.0	21	100.0

Data source; HHs field survey

Conflicts among users in the irrigation system, in Jari SSI scheme 59.3% of the respondents were faced the problem. Additionally the conflicts also extended with WUAs committees; because the WUA committee members were biased to their relatives, selfishness and use their power in illegal ways. While in Aloma the conflict was relatively better, i.e. 42.9% of the respondents were faced conflict with users and WUA committees, the users most of the time tried to respect each other before reached to conflicts.

The main factors for conflicts in Jari SSI scheme were water theft, competition due to increasing number of water users and water scarcity. However, water theft /water abstraction/ was accounts 62.5% of the problems, still it is a serious issue due to lack of strict enforcement of bylaws for illegal water abstractors. This has further intensified illegal practices to obtain water. In Aloma, from the respondents 88.9% of them mentioned that, water theft was the main factors for their conflicts.

Irrigation water users increased during peak period of the second irrigation season, crop water consumption became high and the volume of conveyed water in the canal became low. At this period the competition lifted up and it led to conflicts among users and with WUA committees. This result is supported by Alula (2001) stated that with increasing number of users, conflicts arising from water allocation became more common; water management became more problematic.

Table 4.33: Causes of conflicts over irrigation water

Causes of conflict	Jari			Aloma		
	Frequency	Percent	Rank	Frequency	Percent	Rank
Water scarcity	2	12.5	3	-	-	-
Competition due to increasing number of water users	4	25.0	2	1	11.1	2
Water theft	10	62.5	1	8	88.9	1
Total	16	100.0		9	100.0	

Source; HHs field survey

In addition, district level irrigation experts and DAs did not provide consistent support to WUAs committees in conflict management. As it is known, the task of water and conflict management systems has become more complex and cannot be controlled by the WUA committee alone.

In summary, lack of support from the local stakeholders and inefficiency of the WUA committee in enforcing rules and in resolving conflicts created frustration among beneficiaries. Hence, in recent years, many of them do not request cases of abusers either to WUA committee or social courts.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

From this performance evaluation study can conclude that, beneficiary participation at both irrigation schemes in canal clearing and regular maintenance was very low. The majority of canals were covered by weeds and soils. Because the WUA's organizational function and legal enforcement of bylaws was weak. This also attributed to illegal water abstractions and unfair water distributions in the irrigation schemes. Additionally, in Aloma SSI scheme absence of flow control gates and broken and cracked secondary canals were contributed for high water loss. As a result the two SSI schemes overall water delivery efficiencies were very low and about half of the diverted amount of water was unproductive.

In Jari SSI scheme shortage of water, market, crop damage by insects and diseases, and lack of input utilizations /improved seeds, fertilizer and chemicals/ were the main factors which influence irrigation crop productivity. While in Aloma market, water, shortage of land, lack of input utilization / improved seeds, fertilizer and chemicals/ were inhibits irrigation crop productivity. However, the average land holding size in Aloma is greater than Jari SSI schemes. As a result land shortage may not be the main problem; instead of low land productivity problems in Aloma SSI scheme.

However, Jari SSI scheme was better than Alom SSI scheme in land and water productivity issues. The reasons were in Jari farmers have been used the land intensively and grown high value crops. While in Aloma SSI scheme crop selection problems, concentrated cropping pattern, low irrigation intensities were contributed for low land and water productivity, and low gross return on investment values. Furthermore, the rigid rotational schedule, absence of irrigation scheduling and concentrated cropping pattern arrangements were highly affected the allocation of water distributions in Jari SSI scheme.

The soil nutrient contents of both irrigation schemes are categorized as low in organic matter content, moderate in total nitrogen and low in available phosphorous. Beside this, farmer's fertilizer application rate was far below the recommended rates. In Jari the soil was less responsive for the applied fertilizers and it couldn't boost up the yield of Teff crop. This may be related to the method and time of fertilizer application problems. However, in Aloma the

less amount of fertilizer application limited crop productivity but there was a response for fertilizer application for potato, wheat and teff crops.

Sustainability of irrigation scheme is under risk and the irrigable area has been shrinking from the original area. The main reasons in Jari were excessive flooding from Mile River and broken of cutoff drain, i.e. which divert Kezikaze River. While in Aloma SSI scheme water shortage, structural failures and farmer's low attitude for irrigation agricultural development were the main causes. However, in Jari the irrigated area about 22ha has been destroyed. As a result it needs to take quick mitigation measurements; otherwise the whole irrigable area will be changed to non cultivable area in short period of time. Consequently farmers will be workless and starved. This may create social, economical and political problems in the area in the near future.

Jari's WUAs have a detailed and written internal bylaw than Aloma. However it has not been enforced offenders who make guilty. As a result it should be required to increase the legal enforcement of the bylaws to protect illegal water abstractions and canal breaching, which disturb the fair water distribution systems. Further more in Jari there is on ground practice of water allocations for beneficiaries; however it has not been supported by technical approaches from DAs and district irrigation experts.

Additionally, Jari SSI scheme has better experience in collecting of annual water fees. However, there were gaps in fee collection mechanisms. And they haven't used the collected money for annual maintenance work yet. Thus, this situation hinders the motivation of farmer's attitude in participation and maintenance work.

Generally, in all selected minimum performance indicators, Jari SSI scheme was perform better than Aloma. Finally, this study result will used to observe performance gaps that were identified and to take measurements for better improvement and sustainability of the two SSI schemes.

5.2. Recommendations

- ✚ Water delivery efficiencies at both scheme is very low. Therefore, the conveyance systems should be improved through regular canal cleaning and maintenance of broken irrigation infrastructures.
- ✚ In Aloma SSI scheme rehabilitation of secondary canals and lining of main canals (200m earthen canal part) is required to improve water delivery efficiency in the scheme.
- ✚ Introducing high value crops, agricultural intensification, increasing land and water productivity through integrated management and increasing irrigation intensities are very relevant to increase the output value of production per unit irrigated area and command area in Aloma SSI scheme.
- ✚ Furthermore appropriate cropping pattern with market linkage is crucial for both schemes.
- ✚ To utilize the scarce water resources at both irrigation schemes water allocation shall be carried out based on predetermined and designed cropping pattern with irrigation scheduling.
- ✚ In Aloma scheme improving soil organic contents /conservation agriculture/ and adopting appropriate recommended fertilizer utilization techniques must be followed.
- ✚ It is required to take quick and participatory mitigation measurements to protect the destroying irrigable area by erosion from Mile and Kezikaze rivers in Jari SSI schemes, according to watershed management approaches.
- ✚ Introducing and adopting the new proclamations IWUAs No. 84/2014 of IWUAs, for beneficiaries and related stakeholders is very important.
- ✚ Putting formal way of fee collection mechanisms and preparing of legal receipts, and finally utilize the collected money for maintenance works are relevant to create transparency and to increase farmer's participation.

REFERENCES

- Akkuzu, E., Unal, H.B. and Karatafi, B.S. (2007). Determination of Water Conveyance Loss in the Menemen Open Canal Irrigation Network. *Turk J. Agric*, **31**: 11-22.
- Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998). Crop evapotranspiration. Guidelines for computing crop water requirements. *FAO Irrigation and drainage paper 56*. FAO, Rome.
- Alula, P. (2001). *Institutionalization of irrigation in South Wello*. In: Institutions for Natural Resource Management: Thematic Briefings, FSS (Ethiopia), Alula, Pankhurst, ed., University of Sussex (UK).
- ARDO (2014). *Tehuledere District Agricultural Development Office Annual Report, for 2014/15 production year* (unpublished).
- Awulachew, S. B., Yilma, A. D., Loulseged, M., Loiskandl, W., Ayana, M. and Alamirew, T. (2007). Water resources and irrigation development in Ethiopia. Colombo, Sri Lanka: *International Water Management Institute (IWMI)*, **123**: 66p.
- Awullachew, S. B., Lambisso, R., Asfaw, G., Yilma, A.D. and Moges S.A. (2010a). Characterizing, Assessing of performance and causes of underperformance of irrigation in Ethiopia. *Ethiopian Journal Development Research*.
- Awulachew, S. B., Teklu, E. and Regassa, E. N. (2010b). Irrigation Potential in Ethiopia; Constraints and Opportunities for Enhancing the System. *International Water Management Institute*.
- Bakry, M.F. and Awad, A.M. (1997). Practical Estimation of Seepage Losses along Earthen Canals in Egypt. *Water Resources Management*, **11**: 197–206.
- BCEOM (1999). *Abbay River Basin Integrated Development Master Plan project*. Addis Ababa, Ethiopia.
- Bekele, A. (2011). *Comparative performance assessment of Hora and Jalale Small-Scale irrigation Schemes in Western Oromia*, Ethiopia, MSc Thesis, Arba Minch University, School of Graduate Studies.

- Blank, H.G., Clifford, M. M. and Hammord, M. R. (2002). The Changing Face of Irrigation in Kenya: Opportunities for Anticipating Change in Eastern and Southern Africa. Colombo, Sri Lanka: *International Water Management Institute*.
- 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.
- Bos, M. G., Wolters W., Drovandi, A. and Morabito, J. A. (1991). The Viejo Retamo Secondary Canal-Performance Evaluation (case study). Mendoza, Argentina. *Irrigation and Drainage Systems*, 5: 77-88
- Bos, M.G. (1997). Performance indicators for irrigation and drainage. *Irrigation and Drainage systems*, 11:119-137.
- Bossio, D., Noble, A., Molden, D. and Nangia, V. (2008). Land Degradation and Water Productivity in Agricultural Landscapes. In: *Conserving Land, Protecting Water*, ed., Bossio, D.; Geheb, K. Wallingford, UK: CABI; Colombo, Sri Lanka: International Water Management Institute (IWMI); Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food, pp.20-32. (Comprehensive Assessment of Water Management in Agriculture Series 6).
- Bouyoucos, G.H. (1951). A calibration of the Hydrometer for Making Soil Analysis. *Argon Journal*, 43: 434-438.
- Burt, C.M. and Styles, S.W. (1999). Modern Water Control and Management Practices in Irrigation: Impact on Performance. *International Program for Technology and Research in Irrigation and Drainage*. Water Reports No. 19. The World Bank. FAO, Rome.
- Burton, M., Molden, D. and Skutsch, J. (2000). Benchmarking Irrigation and Drainage System Performance: *Working group on performance indicators and benchmarking*. Rome, Italy: FAO.
- Clarke, D. (1998). CropWat for Windows: User Guide. Version 8. University of Southampton, UK.

- Cottenie, A. (1980). Soil and Plant Testing As a Basis of Fertilizer Recommendations. *FAO Soil Bulletin 38/2*. Food and Agriculture Organization of the United Nations, Rome, Italy.
- CSA (2007). Population projection of Ethiopia. Addis Ababa, Ethiopia.
- Dejen, Z. A., Bart, S. and Laszlo, H. (2012). Comparative Irrigation Performance Assessment in Community-Managed Schemes in Ethiopia. *African Journal of Agricultural Research*. **7(35)**: 4956-4970.
- Dejene, A. and Yilma, S. (2003). *Participatory Local Economic Development: The Case of Small Scale Irrigation in North Wollo, Ethiopia*, A Paper presented on the Second International Policy Research Workshop on the Theme New Theories on Local Economic Development and Globalization.
- Depeweg, H. (1999). Off-Farm Conveyance and Distribution Systems. *Land and Water Engineering. CIGR Handbook of Agricultural Engineering*. Volume I. American Society of Agricultural Engineers (ASAE). USA.
- Devereux, S. (2000). Food Insecurity in Ethiopia. *A discussion paper for DFID. IDS Sussex*.
- Dobermann, A. (2007). *Nutrient Use Efficiency Measurement and Management*. In: IFA International Workshop on Fertilizer Best Management Practices. Brussels, Belgium, pp. 1-28.
- Dobermann, A. and Cassman, K.G. (2005). Cereal Area and Nitrogen Use Efficiency are Drivers of Future Nitrogen Fertilizer Consumption. *Science in China*, **48**: 745-758.
- Douglas, L.V. and Juan, A.S. (1999). Transfer of Irrigation Management Services. Guideline: *Irrigation and Drainage Paper*. No. 58. FAO, Rome.
- Drechsel, P., Heffer, P., Magen, H., Mikkelsen, R. and Wichelns, D. (Eds.) (2015). Managing Water and Fertilizer for Sustainable Agricultural Intensification. *International Fertilizer Industry Association (IFA), International Water Management Institute (IWMI), International Plant Nutrition Institute (IPNI), and International Potash Institute (IPI)*. First edition, Paris, France.

- Ethiopian Panel on Climate Change (EPCC, 2015). First Assessment Report, Working Group II; Climate Change Impact, Vulnerability, Adaptation and Mitigation IV. *Water and Energy*, Published by the Ethiopian Academy of Sciences.
- FAO (1984). Guidelines for Predicting Crop Water Requirements: *Irrigation and Drainage Paper*. No. 24. FAO, Rome.
- FAO (1989). Guideline for Designing and Evaluating Surface Irrigation Systems. *Irrigation and Drainage Paper*. No. 45. FAO, Rome
- FAO (1995). *Irrigation in Africa in Figures*. Water Report No.7. FAO, Rome.
- FAO (1996). Irrigation Scheduling: From theory to practice. *Water Reports*, 8. FAO, Rome.
- FAO (1998). Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements. *FAO Irrigation and Drainage Paper*, 56, Rome.
- FAO (1998). Institutional and Technical Options in the Development and Management of Small-Scale Irrigation. Proceeding of the third session of the Multilateral Cooperation Workshop for Sustainable Agriculture; Forestry and Fisheries Development, Tokyo Japan, February 1995. *FAO Water Paper*, No. 17. Rome.
- FAO (2011). The state of the world's land and water resources for food and agriculture: Managing systems at risk. Rome: FAO and London: *Earth scan*.
- FAO (2012). Crop Yield Response to Water. FAO Irrigation and Drainage Paper No. 66. FAO, Rome.
- Federal Negarit Gazette. (2014): *Irrigation Water Users Association (IWUA) Proclamation No. 841/2014*. Addis Ababa, Ethiopia.
- Heffr, P. and Prud, H. M. (2014). Fertilizer Outlook 2014–2018. Paris, France: *International Fertilizer Industry Association (IFA)*.
- IFA (International Fertilizer Industry Association) (2009). The Global “4R” Nutrient Stewardship Framework. Paris, France: International Fertilizer Industry Association. IFA. 2014. IFADATA. <http://ifadata.fertilizer.org/ucSearch.aspx>.
- Jari-Tehuledere. (2004). *Internal bylaw of Jari-Tehuledere Irrigation Users No. 001/2004E.C (Unpublished)*

- Jorma, R. (1999). *Financing Irrigation Development and Private Sector Initiative with Special Reference to Sub-Saharan Africa*: FAO E-mail conference 15 March to 23 April. Rome.
- Kloezen, W.H. And Garcés-Restrepo. (1998). Assessing Irrigation Performance with Comparative Indicators: *The Case of the Alto Rio Lerma Irrigation District, Mexico*. Vol. Research Report 22 Colombo, Sri Lanka: *International Water Management Institute*.
- Ladha, J.K., Pathak, H., Krupnick, T.J., Six, J. and van Kessel, C. (2005). Efficiency of Fertilizer Nitrogen in Cereal Production: Retrospect and Prospects. *Advances in Agronomy*, **87**: 85-156.
- Lam, W. F. (1996). Improving the Performance of Small-Scale Irrigation Systems: The effect of Technological Investments and Governance Structure on Irrigation Performance in Nepal. *World Development*, **24 (8)**: 1301-1315.
- Lemperiere, P., van der Schans, M. L. and Bavanirajan, V. J. G. (2014). Research for Development Using Participatory Rapid Diagnosis and Action Planning for Irrigated Agricultural Systems: *A Manual for Development Researchers and Practitioners*. Updated edition. Colombo, Sri Lanka: International Water Management Institute (IWMI).
- Levine, G. (1982). Relative Water Supply: An Explanatory Variable for Irrigation Systems. Technical Report No.6. Ithaca, New York, USA: Cornell University.
- Lowdermilk, M. K. (1981). Social and Organizational Aspect of Irrigation System Lecture for Diagnostic Analysis Workshop, *water management synthesis project*, Colorado State University fort Collins, Colorado.
- Luis, S. P. (1999). Higher Performance through Combined Improvements in Irrigation Methods and Scheduling: *a discussion Agricultural Water Management*, **40 (3)**: 153-169.
- Makombe, G., Namara, R., Hagos, F., Awulachew, S.B., Ayana, M. and 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*. pp. 37

- Mazumder, S. K. (1983). *Irrigation Engineering*. Tata McGraw- Hill Publication Company Limited. New Delhi.
- McCornick, P.G., Kamara, A.B. and Girma, T. (2003). *Integrated Water and Land Management Research and Capacity Building Priorities for Ethiopia*. Proceedings of a MoWR /EARO/IWMI/ILRI international workshop held at ILRI, Addis Ababa, Ethiopia, 2–4 December 2002. IWMI (International Water Management Institute), Colombo, Sri Lanka, and ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 267.
- Melkamu, A. (1996). The Role of Small Scale Irrigation Development in the Development of Sustainable Agriculture. *Conference on Ethiopia's Rural-Centered Development and Food Security* 13-19, September 1996. Addis Ababa. Ethiopia.
- Menelik, H. (2008). *Performance Evaluation of Small-Scale Irrigation Scheme: A Case Study of Selgie Irrigation Scheme*, South Wollo, Ethiopia, MSc Thesis, Hramaya University, School of Graduate Studies.
- 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.
- MoA (2015). Ministry of Agriculture Annual report of 2014/15 fiscal year. (Unpublished).
- MoFED (Ministry of Finance and Economic Development) (2010). *Growth and Transformation Plan (GTP) (2010/11 -2014/2015)*. Volume I. Addis Ababa, Ethiopia.
- Molden D. (2007). Ed, *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earth scan and Colombo: *International Water Management Institute*.
- Molden, D., Sakthivadivel, R., Perry, C.J., Fraiture, C.D. and Kloezen, W.H. (1998). *Indicators for Comparing Performance of Irrigated Agricultural Systems*. Vol. Research Report 20 Colombo, Sri Lanka: *International Water Management Institute*.
- MoWR (2002). *Ethiopian Water Sector Development Program 2002-2016*.

- Oad, R. and Sampath, R. K. (1995). Performance Measure for Improving Irrigation Management. *Irrigation and Drainage Systems*, **9**: 357-370.
- Odi (1995). Recent trends in Irrigation Management: Changing Directions for the public Sector, Natural Resource Perspectives; London: UK.
- ORDA (2005). *Proposal for Jari Integrated Watershed Development Project*. Bahir Dar, Ethiopia.
- ORDA (Organization for Rehabilitation and Development in Amhara) (2005). Jari-Fulwaha Agricultural Comprehensive Development and programming in Upper Mile River Design Document.
- Rao, P.S. (1993). Review of Selected Literature on Indicators of Irrigation Performance. IIMI Research Paper No.13. Colombo, Sri Lanka: *International Irrigation Management Institute*.
- Şener, M., Yüksel, AN and Konukcu, F. (2007). Evaluation of Hayrabolu Irrigation Scheme in Turkey Using Comparative Performance Indicators. *J. Tekirdag Agric. Fac.* pp. 1-4.
- Sisay, Demeku., Katrin, D., Amare, Hailelassie. and Tilahun, Amede. (2009). Irrigation Water Productivity As Affected By Water Management in a Small-Scale Irrigation Scheme in The Blue Nile Basin, Ethiopia. (Unpublished).
- Small, L. E. and Svendsen, M. (1992). A Framework for Assessing Irrigation Performance. International Food Policy Research Institute Working Papers on Irrigation Performance. No.1. Washington, D. C: *International Food Policy Research Institute*.
- Tekalign, T. (1991). Soil, Plant, Water, Fertilizer, Animal Manure and Compost Analysis. Working Document. No.13. *International Livestock Research Center for Africa*, Addis Ababa, Ethiopia.
- Waraich, E.A., Ahmad, R., Ashraf, Y. M., Saifullah, S. and Ahmad, M. (2011). Improving Agricultural Water Use Efficiency by Nutrient Management in Crop Plants. *Acta Agriculturae Scandinavica Section B: Soil and Plant Science*, **61(4)**: 291-304.

- Water Conservation Fact Sheet (WCFS). 2002. Soil water storage capacity and available soil moisture. British Columbia Ministry of Agriculture, *Food and Fisheries*. Agdex: 550. Abbotsford, BC. Canada.
- Wil, N. M. Van der Krogt. (1994). OMIS: A model package for irrigation system management. *Water Reports 2*. FAO, Rome.
- Woldeab, T. (2003). *Irrigation Practices, State Intervention and Farmers Life-worlds in Drought Prone Tigray, Ethiopia* (PhD Dissertation).
- Yakob, W. and Melaku, T., (2006). Household Water Harvesting and Small Scale Irrigation Schemes in Amhara Region, SWHISA project Bahir Dar. **In:** *Best practices and technologies for small scale agricultural water management in Ethiopia. Proceeding of MoARD/MoWR/IWMI symposium and exhibition held at Gion Hotel*. Addis Abeba, Ethiopia, March 7-9, 2006.
- Yalew, B. (2006). Current Experience on Existing Small Scale Irrigations. **In:** *Best practices and technologies for small agricultural water management in Ethiopia*. Proceeding of a MoARD/MoWR/USAID/IWMI symposium and exhibition held at Gion Hotel, Addis Abeba, Ethiopia, March 7-9, 2006.
- Yamane, T. (1967). *Statistics: An Introductory Analysis*, 2nd Ed., New York: Harper and Row.

LIST OF APPENDIX TABLES

Appendix table 1: Mean monthly rainfall and effective rainfall (USDA SCS method) for Jari irrigation scheme

Months	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	60	43.5	108.4	99.0	60.1	22.9	229.0	239.4	105	39.5	26.9	32.1	1065.9
Effective rainfall	54.2	40.5	89.6	83.3	54.3	22	145.1	147.7	87.4	37.0	25.7	30.4	817.4

Appendix table 2: Mean monthly rainfall and effective rainfall (USDA SCS method) for Aloma irrigation scheme

Months	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	19.3	27.7	95.5	96.7	67.9	40.6	341.1	313.4	110.2	39.6	30	23.0	1202
Effective rainfall	18.7	26.5	80.9	81.7	60.5	38.0	159.1	156.3	90.8	37.1	25.8	22.2	797.6

Appendix table 3: Mean monthly meteorological data and ETo values of Jari irrigation scheme

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m ² /day	ETo mm/day
January	11.9	24.2	57	138	7.3	17.9	3.66
February	14.1	25.0	58	164	7.1	18.9	4.08
March	13.5	26.8	54	164	6.7	19.4	4.52
April	13.2	27.8	53	138	7.0	20.3	4.61
May	13.9	29.4	44	181	7.6	20.9	5.32
June	15.1	31.5	36	199	6.3	18.6	5.71
July	12.7	30.1	51	173	4.8	16.5	4.71
August	11.9	28.1	56	138	5.4	17.6	4.25
September	13.7	27.8	58	112	5.4	17.5	3.99
October	13.3	27.1	55	104	7.5	19.7	4.12
November	12.3	26.0	53	104	8.0	19.0	3.80
December	13.0	25.5	55	147	7.0	17.0	3.76
Average	13.2	27.4	52	147	6.7	18.6	4.38

Appendix table 4: Mean monthly meteorological data and ETo values of Aloma irrigation scheme

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\SSI\EToaloma.pem							
Country		Ethiopia		Station		Aloma	
Altitude		2033 m.		Latitude		11.27 °N	
				Longitude		39.68 °E	
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m ² /day	mm/day
January	8.2	24.1	51	138	7.1	17.6	3.68
February	8.1	25.7	51	164	7.0	18.7	4.21
March	10.1	26.6	46	164	6.6	19.3	4.59
April	11.8	27.0	46	138	7.0	20.3	4.65
May	12.1	28.4	38	181	7.5	20.8	5.35
June	12.3	30.0	31	199	6.2	18.5	5.60
July	13.7	27.5	47	173	4.5	16.0	4.49
August	13.5	26.0	53	138	5.1	17.2	4.14
September	12.1	26.2	51	112	5.2	17.2	3.99
October	8.3	25.8	48	104	7.5	19.7	4.08
November	6.8	25.1	45	104	7.9	18.9	3.77
December	7.9	22.8	50	147	6.9	16.9	3.54
Average	10.4	26.3	46	147	6.5	18.4	4.34

Appendix table 5: Yield samples for major crops at each SSI scheme

Scheme	Crop types	Statistical parameters	Yield (Ql/ha)		Scheme	Crop types	Statistical parameters	Yield (Ql/ha)	
			With fertilizer	with out				With fertilizer	with out
Jari	Teff	N	4	4	Aloma	Wheat	N	6	6
		Mean	12.83	12.38			Mean	37.43	23.18
		SE	0.7	0.23			SE	1.5	1.07
		CV (%)	1.96	0.2			CV (%)	13.25	13.53
Aloma	Potato	N	3	3		Teff	N	3	3
		Mean	325.5	219.5			Mean	20.75	14.19
		SE	-	-			SE	0.93	1.36
		CV (%)	-	-			CV (%)	5.26	5.23

Appendix table 6: Crops area coverage and planting date at Jari and Aloma SSI schemes

Jare SSI									
Irrigation seasons									
S. No	Types of Crops	Season I				Season II			
		Area (%)	Area (ha)	Planting date	LGP (days)	Area (%)	Area (ha)	Planting date	LGP (days)
1	Chick pea	33	33.7	15/9/14	90	-	-	-	-
2	Green maize	27	27.5	1/11/15	90	24	27.6	1/3/15	90
3	Pepper	20	20.4	1/11/5	120	10	11.5	15/2/15	120
4	Mango**	5	5.1	1/9/14	273	-	-	-	-
5	Avocado**	3	3.1	1/9/14	273	-	-	-	-
6	Orange **	4.5	4.6	1/9/14	273	-	-	-	-
7	Banana**	2.5	2.6	1/9/14	273	-	-	-	-
8	Sugar Cane*	5	5.1	1/9/14	273	-	-	-	-
9	Teff	-	-	-	-	35	40.3	1/3/15	100
12	Tomato	-	-	-	-	4.25	4.9	15/2/15	115
13	Onion	-	-	-	-	5	5.8	1/3/15	100
14	Cabbage	-	-	-	-	4	4.6	15/2/15	120
Total		100	102			82.25	94.6		
						(#18)	(20.5#)		

Aloma SSI									
1	Teff	-	-	-	-	36	32.4	1/3/15	110
2	Wheat	-	-	-	-	40	36	1/3/15	115
3	Potato	-	-	-	-	6.5	5.85	1/3/15	120
4	Chick pea	-	-	-	-	9	8.1	1/3/15	100
5	Green maize	-	-	-	-	6	5.4	1/3/15	105
6	Haricot bean	-	-	-	-	2.5	2.25	1/3/15	100
Total						100	90		

Appendix table 7: Monthly net scheme irrigation requirements of a given cropping pattern

Irrigation scheme								
Months	Jari				Aloma			
	NSIR (l/s/ha)	Irrigated area (%)	Area (ha)	NSIR (l/s)	NSIR (l/s/ha)	Irrigated area (%)	Area (ha)	NSIR (l/s)
Sep	0.01	39	48.75	0.49	0	0	0	0
Oct	0.13	43	53.75	6.99	0	0	0	0
Nov	0.19	81	101.25	19.24	0	0	0	0
Dec	0.19	54	67.5	12.83	0	0	0	0
Jan	0.13	54	67.5	8.78	0	0	0	0
Feb	0.12	49	61.25	7.35	0	0	0	0
Mar	0.06	60	75	4.50	0	43	49.45	0
Apr	0.21	92	115	24.15	0.17	78	89.7	15.249
May	0.36	92	115	41.40	0.34	78	89.7	30.498
Jun	0.07	54	67.5	4.73	0.19	78	89.7	17.043

Where; NSIR= net scheme irrigation requirements

Appendix table 8: Jari weekly flow variations at intake

Date	Weeks	Q(l/s)
20/3/15	1	28.23
27/3/15	2	37.82
3/4/15	3	36.04
10/4/15	4	29.84
17/4/15	5	31.70
24/4/15	6	32.22
1/5/15	7	30.53
8/5/15	8	52.11
29/5/15	11	54.00
5/6/15	12	23.71
Mean		35.62
SE		3.16
SD		9.99
CV (%)		99.74

Appendix table 9: Jari monthly flow variations at intake

Months	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Mean	SE	SD	CV (%)
Q (l/s)	40.0	40.0	39.0	38.0	33.5	29.8	33.0	32.5	45.6	23.7	35.5	1.98	6.3	39.1

Appendix table 10: Aloma weekly flow variations at intake

Date	11/8/2007	18/8/2007	25/8/07	2/9/207	23/09/07	N	Mean	SE	SD	CV (%)
Q(l/s)	62.41	57.01	54.66	54.66	62.04	5	58.16	1.72	3.84	14.72

Appendix table 11: Aloma mothly flow variations at intake

Months	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Mean	SE	SD	CV (%)
Q (l/s)	58.0	55.9	53.9	52.0	50.1	48.3	58	58.03	58.35	61.50	55.42	1.33	4.20	17.65

Appendix table 12: Main canal conveyance efficiency and losses at Jari

Canal reaches	Observations	Qi(l/s)	Qo(l/s)	CE (%)	Losses (ls ⁻¹ /m)
MC1 (Head reach)	1	28.23	27.84	0.99	0.004
	2	37.82	36.49	0.96	0.013
	3	36.04	33.92	0.94	0.021
	4	29.84	29.30	0.98	0.005
	5	31.70	30.89	0.97	0.008
	6	32.22	30.89	0.96	0.013
	7	30.53	28.53	0.93	0.020
	8	52.11	51.10	0.98	0.010
	9	54.00	51.25	0.95	0.027
	10	23.71	22.58	0.95	0.011

Average		35.62	34.28	0.96	0.013
MC2 (Middle reach)	1	28.23	25.81	0.91	0.008
	2	37.82	33.19	0.88	0.015
	3	36.04	31.91	0.89	0.014
	4	29.84	27.01	0.91	0.009
	5	31.70	27.85	0.88	0.013
	6	32.22	27.25	0.85	0.017
	7	30.53	25.80	0.85	0.016
	8	52.11	46.24	0.89	0.020
	9	54.00	48.13	0.89	0.020
	10	23.71	19.55	0.82	0.014
Average		35.62	31.28	0.88	0.014
MC3 (Middle reaches)	1	28.23	21.50	0.76	0.012
	2	37.82	29.19	0.77	0.016
	3	36.04	26.59	0.74	0.017
	4	29.84	22.51	0.75	0.013
	5	31.70	24.04	0.76	0.014
	6	32.22	23.10	0.72	0.017
	7	30.53	20.25	0.66	0.019
	8	52.11	38.53	0.74	0.025
	9	54.00	41.50	0.77	0.023
	10	23.71	16.00	0.67	0.014
Average		35.62	26.32	0.73	0.017
MC4 (tail reach)	1	28.23	17.01	0.60	0.014
	2	37.82	23.00	0.61	0.019
	3	36.04	22.00	0.61	0.018
	4	29.84	18.30	0.61	0.014
	5	31.70	18.49	0.58	0.017
	6	32.22	20.12	0.62	0.015
	7	30.53	17.50	0.57	0.016
	8	52.11	31.00	0.59	0.026
	9	54.00	28.00	0.52	0.033
	10	23.71	14.40	0.61	0.012
Average		35.62	20.89	0.59	0.018

Appendix table 13: Main canal conveyance efficiency at Aloma SSI scheme

Canal reaches	Observations	Qi(l/s)	Qo(l/s)	CE (%)	Losses (ls ⁻¹ /m)
MC1 (Head reach)	1	62.41	59.22	0.95	0.009
	2	57.01	53.93	0.95	0.009
	3	54.66	52.52	0.96	0.006
	4	54.66	52.89	0.97	0.005
	5	62.04	60.52	0.98	0.004
	Average	58.16	55.82	0.96	0.007
MC2 (Head reach)	1	62.41	56.44	0.90	0.010
	2	57.01	51.47	0.90	0.009
	3	54.66	48.15	0.88	0.011
	4	54.66	50.76	0.93	0.007
	5	62.04	58.84	0.95	0.005
	Average	58.16	53.13	0.91	0.008
MC3 (Middle reach)	1	62.41	52.57	0.84	0.012
	2	57.01	49.01	0.86	0.010
	3	54.66	46.81	0.86	0.010
	4	54.66	48.69	0.89	0.007
	5	62.04	57.65	0.93	0.005
	Average	58.16	50.95	0.88	0.009
MC4 (Middle reach)	1	62.41	46.46	0.74	0.017
	2	57.01	43.05	0.76	0.015
	3	54.66	44.21	0.81	0.011
	4	54.66	45.58	0.83	0.010
	5	62.04	49.07	0.79	0.014
	Average	58.16	45.67	0.79	0.013
MC5 (Tail reach)	1	62.41	38.29	0.61	0.021
	2	57.01	39.14	0.69	0.016
	3	54.66	40.30	0.74	0.012
	4	54.66	41.51	0.76	0.011
	5	62.04	41.68	0.67	0.018
	Average	58.16	40.18	0.69	0.016

Appendix table 14: Secondary canal conveyance efficiency at Jari SSI scheme

Canal locations	Observations (N)	Inflow (l/s)	Out flow (l/s)	CE (%)	Losses (ls ⁻¹ /100m)	% Losses (ls ⁻¹ /100m)
SC1	1	27.47	24.29	0.88	0.64	2.31
	2	33.92	30.16	0.89	0.75	2.22
	3	29.30	27.82	0.95	0.30	1.01
	4	49.25	45.93	0.93	0.66	1.35
	5	22.58	19.67	0.87	0.58	2.58
	6	27.47	24.04	0.88	0.69	2.50
	7	33.92	28.89	0.85	1.01	2.97
	8	29.30	27.30	0.93	0.40	1.36
	9	49.25	43.98	0.89	1.05	2.14
	10	22.58	18.76	0.83	0.77	3.39
	Average	32.51	29.08	0.89	0.68	2.18
SC2	1	33.19	29.91	0.90	0.66	1.98
	2	33.19	29.84	0.90	0.67	2.02
	Average	33.19	29.87	0.90	0.66	2.00
SC3	1	18.90	14.82	0.78	0.82	4.31
	2	18.90	14.36	0.76	0.91	4.81
	Average	18.90	14.59	0.77	0.86	4.56
SC4	1	24.85	20.58	0.83	0.86	3.44
	2	24.85	21.60	0.87	0.65	2.62
	Average	24.85	21.09	0.85	0.75	3.03
Over all mean		29.93	26.37	0.87	0.71	2.56
SE		2.25	2.22	0.01	0.05	0.26
SD		9.00	8.90	0.05	0.20	1.03
CV (%)		81.06	79.18	0.30	0.04	1.07

Appendix table 15: Secondary canal conveyance efficiency at Aloma SSI scheme

Canal locations	Observations (N)	Inflow (l/s)	Out flow (l/s)	CE (%)	Losses (ls ⁻¹ /100m)	% Losses (ls ⁻¹ /100m)
Sc3	1	38.29	30.42	0.79	2.25	5.87
	2	39.14	31.17	0.80	2.28	5.82
	3	42.30	36.68	0.87	1.61	3.80
	4	43.51	35.63	0.82	2.25	5.17
	5	41.68	34.30	0.82	2.11	5.05
	Average	40.98	33.64	0.82	2.10	5.14
Sc5	1	38.29	29.69	0.78	2.46	6.42
	2	39.14	28.20	0.72	3.13	7.99
	3	42.30	32.72	0.77	2.74	6.47
	4	43.51	34.44	0.79	2.59	5.95

	5	41.68	32.71	0.78	2.56	6.15
	Average	40.98	31.55	0.77	2.69	6.60
Over all mean		40.98	32.60	0.79	2.40	5.87
SE		0.65	0.86	0.01	0.13	0.34
SD		2.07	2.72	0.04	0.41	1.09
CV (%)		4.27	7.42	0.10	0.16	1.19

Appendix table 16: Volume of water distributed along the canal reaches at Jari

Canal reaches	Farm plot	command area (ha)	Discharge (l/s)	Duration of irrigation (hr)	Volume (m ³)	Volume (m ³ /ha)
Head	1	0.5	8.3875	6.13	184.9	370
	2	0.04	8.1875	0.54	15.8	396
	3	0.11	8.0625	1.51	43.9	399
	Average	0.217	8.213	2.7	81.6	388
Middle	1	0.09	7.9375	1.13	32.1	357
	2	0.25	8.3125	2.70	80.8	323
	3	0.12	7.9375	1.38	39.3	327
	Average	0.153	8.063	1.73	50.75	336
Tail	1	0.3	8.125	3.3125	96.9	323
	2	0.25	8.375	2.31	69.7	279
	3	0.25	8.125	1.94	56.7	227
	Average	0.33	8.21	3.10	74.43	276

Appendix table 17: Volume of water distributed along the canal reaches at Aloma

Canal reaches	Farm plot	Command area (ha)	Discharge (l/s)	Duration of irrigation (hr)	Volume (m ³)	Volume (m ³ /ha)
Head	1	0.75	5.88	5.75	121.6	162
	2	0.25	5.75	2.88	59.5	238
	3	0.175	6	2.50	54.0	309
	Average	0.39	5.88	3.71	78.38	236
Middle	1	0.25	5.75	2.88	59.5	238
	2	0.5	5	5.13	92.3	185
	3	0.75	5.5	5.63	111.4	149
	Average	0.50	5.42	4.54	87.71	190
Tail	1	0.25	5.06	2.75	50.1	200
	2	0.50	5.06	3.13	57.0	114
	3	0.02	3.63	0.29	3.8	188
	Average	0.26	4.58	2.05	36.94	167

Appendix table 18: Crops characteristic data for Jari SSI scheme

Crop	Factors	Growth stages					Factors	Growth stages				
		I	D	M	L	Total		I	D	M	L	Total
Tomato	Kc	0.45	-	1.15	0.8	-	P	0.3	-	0.4	0.5	-
	LGP	20	30	45	20	115	Ky	0.45	1.1	0.8	0.4	1.08
	Z (m)	0.25	-	-	1.1	-	Hm(m)	-	-	-	-	0.6
Onion	Kc	0.7	-	1.05	0.75	-	P	0.2	-	0.3	0.3	-
	LGP	15	25	45	15	100	Ky	0.45	1	0.8	0.3	1.1
	Z (m)	0.2	-	-	-	0.6	Hm(m)	-	-	-	-	0.4
Pepper	Kc	0.6	-	1.05	0.9	-	P	0.2	-	0.3	0.5	-
	LGP	20	35	45	20	120	Ky	0.5	1	1.1	0.8	1.1
	Z (m)	0.25	-	-	0.8	-	Hm(m)	-	-	-	-	0.7
Cabbage	Kc	0.7	-	1.05	0.95	-	P	0.4	-	0.4	0.4	-
	LGP	25	30	45	20	120	Ky	0.2	0.8	0.7	0.6	0.95
	Z (m)	0.25	-	-	0.6	-	Hm(m)	-	-	-	-	0.4
Teff	Kc	0.25	-	0.95	0.41	-	P	0.4	-	0.4	0.6	-
	LGP	15	30	40	15	100	Ky	0.5	0.6	1	0.6	1
	Z (m)	0.1	0.3	0.5	0.5	0.5	Hm(m)	-	-	-	-	0.8
Green Maize	Kc	0.4	-	1.15	0.75	-	P	0.3	-	0.3	0.7	-
	LGP	15	25	35	15	90	Ky	0.4	1	1.3	0.5	1.25
	Z (m)	0.3	-	-	-	0.8	Hm(m)	-	-	-	-	2
Chick pea	Kc	0.3	-	1	0.5	-	P	0.5	-	0.5	0.8	-
	LGP	15	25	35	15	90	Ky	0.4	1	1.3	0.5	1.25
	Z (m)	0.3	-	-	-	0.8	Hm(m)	-	-	-	-	0.6
Fruits (orange , mango,	Kc	0.9	-	1.1	1	-	P	0.5	-	0.5	0.6	0.5
	LGP	23	70	120	60	273	Ky	0.5	0.7	1	0.6	0.9

Avocado)	Z (m)	0.5	-	-	-	3	Hm(m)	-	-	-	-	4
Sugar cane	Kc	0.4	-	1.25	0.8	-	P	0.4	-	0.4	0.65	
	LGP	25	70	130	48	273	Ky	0.75	1	0.6	0.4	1.2
	Z (m)	0.5	-	-	-	1.5	Hm(m)	-	-	-	-	2.5
Banana	Kc	1	-	1.2	1.1	-	P	0.4	-	0.4	0.4	-
	LGP	30	49	180	14	273	Ky	0.5	0.8	1	0.6	1.3
	Z (m)	0.8	-	-	1.5	-	Hm(m)	-	-	-	-	3.5

Appendix table 19: Crops characteristic data for Aloma SSI scheme

Crop	Factors	Growth stages					Factors	Growth stages				
		I	D	M	L	Total		I	D	M	L	Total
Wheat	Kc	0.3	-	1.15	0.35	-	P	0.3	-	0.4	0.8	0.55
	LGP	15	35	45	20	115	Ky	0.2	0.65	0.55	-	1.05
	Z (m)	0.3	-	-	1	-	Hm(m)	-	-	-	-	1
Teff	Kc	0.25	-	0.95	0.41	-	P	0.4	-	0.5	-	0.6
	LGP	15	35	45	15	110	Ky	0.5	0.6	1	0.6	1
	Z (m)	0.1	-	-	-	0.5	Hm(m)	-	-	-	-	0.8
Green Maize	Kc	0.4	-	1.15	0.75	-	P	0.3	-	0.4	0.7	-
	LGP	15	30	45	15	105	Ky	0.4	1	1.3	0.5	1.25
	Z (m)	0.3	-	-	1	0.8	Hm(m)	-	-	-	-	2
Potato	Kc	0.5	-	1.15	0.5	-	P	0.4	-	0.4	0.7	-
	LGP	20	35	45	20	120	Ky	0.4	0.8	1	0.7	1.1
	Z (m)	0.3	-	-	1	-	Hm(m)	-	-	-	-	0.6
Chick pea	Kc	0.2	-	1	0.35	-	P	0.5	-	0.5	0.8	-
	LGP	15	30	40	15	100	Ky	0.4	1	1.3	0.5	1
	Z (m)	0.3	-	-	-	0.8	Hm(m)	-	-	-	-	0.4
Haricot bean	Kc	0.4	-	1.15	0.35	-	P	0.3	-	0.5	0.5	-
	LGP	15	30	40	15	100	Ky	0.5	1	0.8	0.5	1
	Z (m)	0.3	-	-	-	0.5	Hm(m)	-	-	-	-	0.5

Where; LGP-length of growing period, P-depletion fraction, Z-crop root zone, Kc- crop coefficient, Ky yield reduction factor and Hm- maximum crop height.

Source: FAO I & D 24 (1992) and 56 (1998) papers and from house hold survey.

Appendix table 20: Chick pea irrigation requirement at Jari SSI scheme

Planting date: 15/9/14

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Sep	2	Init	0.3	1.2	7.2	17.2	0
Sep	3	Deve	0.3	1.22	12.2	23.2	0
Oct	1	Deve	0.48	1.95	19.5	16.7	2.8
Oct	2	Deve	0.75	3.1	31	10.5	20.5
Oct	3	Mid	0.97	3.9	42.9	9.9	33
Nov	1	Mid	0.99	3.86	38.6	9.4	29.2
Nov	2	Mid	0.99	3.75	37.5	7.9	29.6
Nov	3	Late	0.98	3.7	37	8.6	28.4
Dec	1	Late	0.74	2.78	27.8	9.1	18.8
Dec	2	Late	0.52	1.96	5.9	2.8	1.2
Total					259.6	115.3	163.5

Appendix table 21: Chick pea crop irrigation scheduling at Jari SSI scheme

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
30-Sep	16	Dev	0	1	100	12	5.7	0	0	12.7	0.09
16-Oct	32	Dev	0	1	100	35	21.1	0	0	46.8	0.34
30-Oct	46	Mid	0	0.85	99	62	40.6	0	0	90.3	0.75
13-Nov	60	Mid	4.1	0.9	98	60	39	0	0	86.6	0.72
27-Nov	74	Mid	4.5	0.92	99	59	38.4	0	0	85.3	0.7
13-Dec	End	End	0	1	0	44					

Appendix table 22: Onion irrigation requirement at Jari SSI scheme

Planting date: 1/3/15

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Mar	1	Init	0.7	3.06	30.6	26.1	4.5
Mar	2	Deve	0.72	3.26	32.6	32.5	0.2
Mar	3	Deve	0.86	3.9	43	30.9	12.1
Apr	1	Mid	1.01	4.61	46.1	29.2	17
Apr	2	Mid	1.06	4.88	48.8	28.8	20
Apr	3	Mid	1.06	5.14	51.4	25.3	26.1
May	1	Mid	1.06	5.39	53.9	21.4	32.5
May	2	Mid	1.06	5.64	56.4	18.2	38.2
May	3	Late	1.01	5.51	60.6	14.6	46
Jun	1	Late	0.84	4.73	37.8	4.8	31.8
Total					461.2	231.8	228.2

Appendix table 23: Onion crop irrigation scheduling at Jari SSI scheme

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
2-Mar	2	Init	0	0.54	58	63	17.6	0	0	39	2.26
4-Mar	4	Init	0	1	100	21	6.3	0	0	14	0.81
6-Mar	6	Init	0	1	100	20	6.3	0	0	14	0.81
8-Mar	8	Init	0	1	100	18	6.1	0	0	13.6	0.79
10-Mar	10	Init	0	1	100	17	6.1	0	0	13.6	0.79
12-Mar	12	Init	0	1	100	17	6.5	0	0	14.5	0.84
14-Mar	14	Init	0	1	100	16	6.5	0	0	14.5	0.84
18-Mar	18	Dev	0	1	100	15	6.5	0	0	14.5	0.42
22-Mar	22	Dev	0	1	100	30	14.3	0	0	31.9	0.92
26-Mar	26	Dev	0	1	100	30	15.6	0	0	34.7	1
30-Mar	30	Dev	0	1	100	28	15.6	0	0	34.7	1
3-Apr	34	Dev	17.5	1	100	8	4.6	0	0	10.3	0.3
7-Apr	38	Dev	17.5	1	100	7	4.6	0	0	10.3	0.3
11-Apr	42	Mid	0	1	100	29	18.7	0	0	41.6	1.2
15-Apr	46	Mid	0	1	100	23	14.7	0	0	32.6	0.94
19-Apr	50	Mid	0	1	100	23	14.7	0	0	32.6	0.94
23-Apr	54	Mid	14.8	1	100	8	5.5	0	0	12.2	0.35
27-Apr	58	Mid	14.8	1	100	9	5.8	0	0	12.8	0.37
1-May	62	Mid	0	1	100	32	20.8	0	0	46.2	1.34
5-May	66	Mid	0	1	100	25	16.2	0	0	35.9	1.04
9-May	70	Mid	0	1	100	25	16.2	0	0	35.9	1.04
13-May	74	Mid	10	1	100	19	12.3	0	0	27.4	0.79
17-May	78	Mid	10	1	100	19	12.6	0	0	27.9	0.81
21-May	82	Mid	0	1	100	34	22.4	0	0	49.8	1.44
26-May	87	End	0	1	100	34	22	0	0	48.9	1.13
31-May	92	End	0	0.94	99	42	27.2	0	0	60.5	1.4
5-Jun	97	End	0	1	100	33	21.3	0	0	47.2	1.09
8-Jun	End	End	0	1	100	11					

Appendix table 24: Teff irrigation requirement at Aloma SSI scheme

Planting date: 1/3/15

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Mar	1	Init	0.25	1.12	11.2	22.6	0
Mar	2	Deve	0.28	1.29	12.9	29.5	0
Mar	3	Deve	0.48	2.2	24.2	28.7	0
Apr	1	Deve	0.69	3.21	32.1	27.8	4.3
Apr	2	Mid	0.9	4.17	41.7	28.2	13.5
Apr	3	Mid	0.97	4.75	47.5	25.6	21.9
May	1	Mid	0.97	4.97	49.7	22.5	27.2

May	2	Mid	0.97	5.2	52	20.2	31.8
May	3	Mid	0.97	5.28	58.1	17.7	40.4
Jun	1	Late	0.87	4.84	48.4	10.6	37.7
Jun	2	Late	0.54	3.08	24.6	4.7	18.8
Total					402.3	238.1	195.6

Appendix table 25: Teff crop irrigation scheduling at Aloma SSI scheme

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
4-Mar	4	Init	0	1	89	19	3	0	0	6.7	0.19
8-Mar	8	Init	0	1	100	13	2.5	0	0	5.7	0.16
12-Mar	12	Init	0	1	100	23	5.4	0	0	12.1	0.35
20-Mar	20	Dev	0	1	100	17	5.2	0	0	11.5	0.17
28-Mar	28	Dev	0	1	100	11	4.4	0	0	9.8	0.14
5-Apr	36	Dev	0	1	100	21	9.6	0	0	21.4	0.31
13-Apr	44	Dev	16.8	1	100	16	8.5	0	0	19	0.27
20-Apr	51	Mid	0	1	100	28	16.7	0	0	37.1	0.61
27-Apr	58	Mid	15	1	100	15	8.7	0	0	19.4	0.32
4-May	65	Mid	0	1	100	35	21.2	0	0	47.2	0.78
11-May	72	Mid	0	1	100	42	25.1	0	0	55.8	0.92
18-May	79	Mid	0	1	100	33	19.9	0	0	44.2	0.73
25-May	86	Mid	0	1	100	45	27	0	0	60	0.99
1-Jun	93	Mid	0	1	100	52	31.2	0	0	69.4	1.15
10-Jun	102	End	0	1	100	61	36.8	0	0	81.7	1.05
18-Jun	End	End	0	1	100	36					

Appendix table 26: Potato irrigation requirement at Aloma SSI scheme

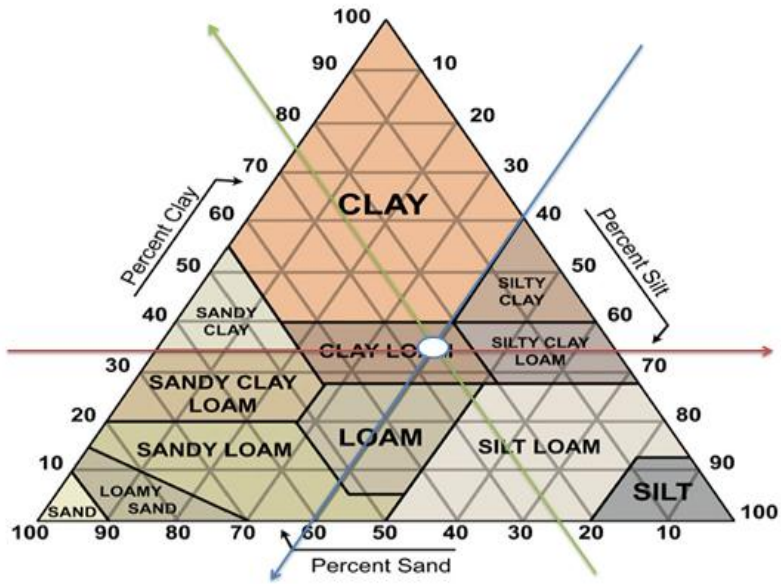
Planting date: 1/3/15

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Mar	1	Init	0.5	2.23	22.3	22.6	0
Mar	2	Init	0.5	2.29	22.9	29.5	0
Mar	3	Deve	0.62	2.84	31.2	28.7	2.5
Apr	1	Deve	0.82	3.78	37.8	27.8	10
Apr	2	Deve	1.01	4.7	47	28.2	18.7
Apr	3	Mid	1.16	5.67	56.7	25.6	31.2
May	1	Mid	1.17	6	60	22.5	37.5
May	2	Mid	1.17	6.28	62.8	20.2	42.6
May	3	Mid	1.17	6.37	70.1	17.7	52.4
Jun	1	Late	1.16	6.49	64.9	10.6	54.3
Jun	2	Late	0.93	5.32	53.2	5.9	47.3
Jun	3	Late	0.65	3.42	27.4	17.3	5.8
Total					556.4	256.5	302.4

Appendix table 27: Potato crop irrigation scheduling at Aloma SSI scheme

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
6-Mar	6	Init	0	0.94	92	48	21.8	0	0	48.4	0.93
12-Mar	12	Init	0	1	100	30	16.5	0	0	36.7	0.71
18-Mar	18	Init	0	1	100	7	4.6	0	0	10.2	0.2
26-Mar	26	Dev	0	1	100	15	11.3	0	0	25.2	0.36
3-Apr	34	Dev	16.5	1	100	10	9	0	0	20	0.29
11-Apr	42	Dev	0	1	100	20	19.8	0	0	44.1	0.64
19-Apr	50	Dev	0	1	100	14	16	0	0	35.7	0.52
3-May	64	Mid	12.9	1	100	30	36.6	0	0	81.3	0.67
17-May	78	Mid	11.3	1	100	42	50.4	0	0	112	0.93
31-May	92	Mid	0	0.8	98	56	67.2	0	0	149.3	1.23
17-Jun	109	End	0	0.65	92	73	87.3	0	0	194.1	1.32
28-Jun	End	End	0	1	0	5					

LIST OF APPENDIX FIGURES

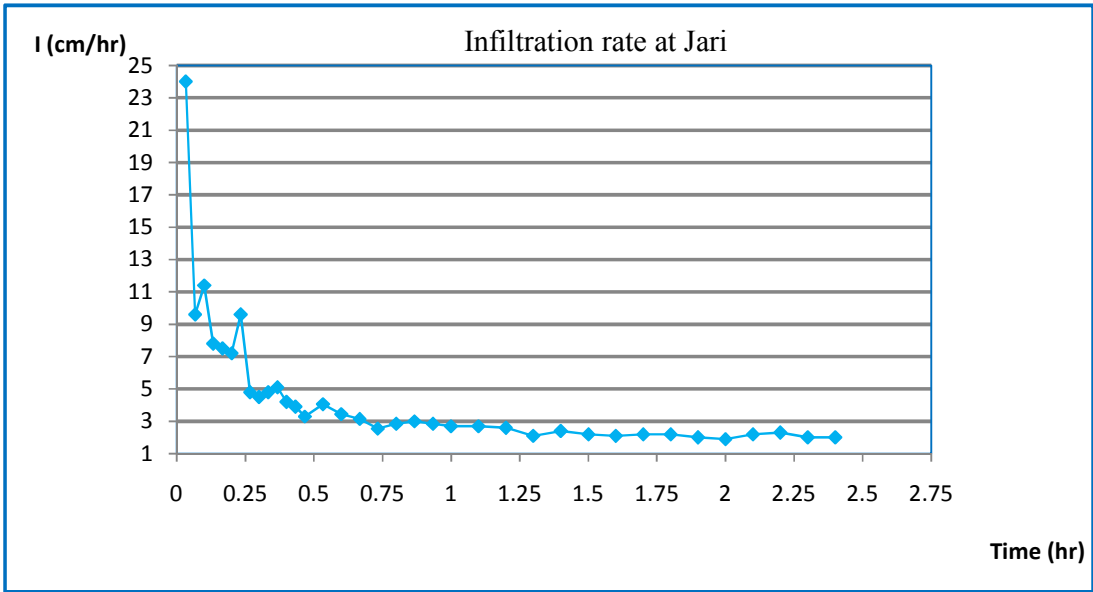


Appendix figure 1: Determination of soil textural class

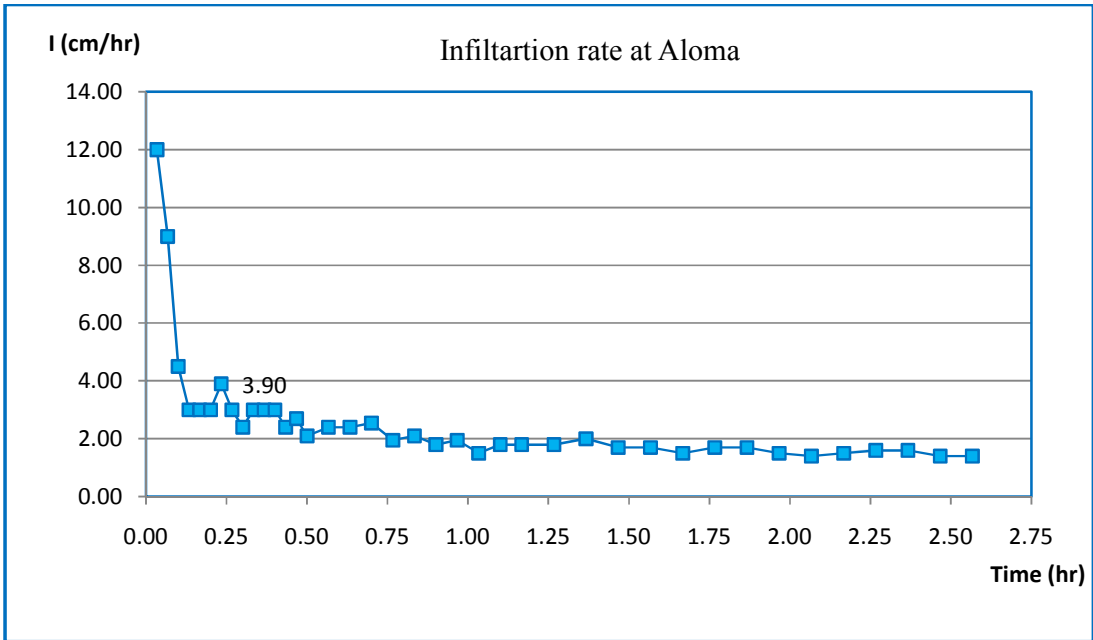


Photo: Solomon Wondatir, April 2015

Appendix figure 2: Field soil infiltration rate test



Appendix figure 3: Soil infiltration rate graph at Jari



Appendix figure 4: Soil infiltration rate graph at Aloma



Appendix figure 5: Water flow rate measurement through Cut-Roat Flume



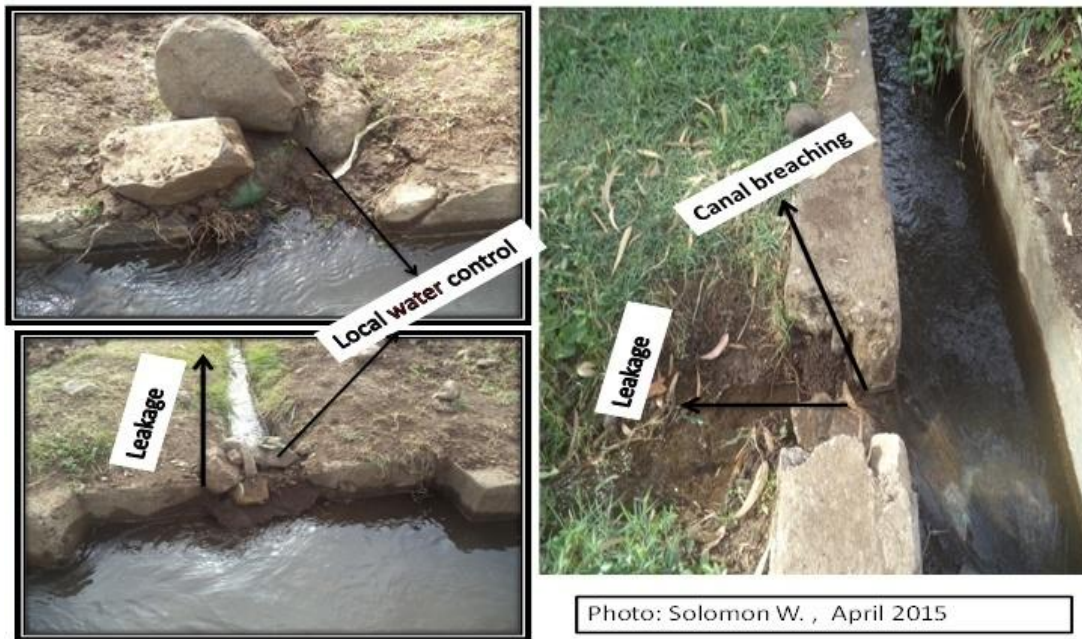
Appendix figure 6: Water stressed Teff crops at Jari SSI scheme



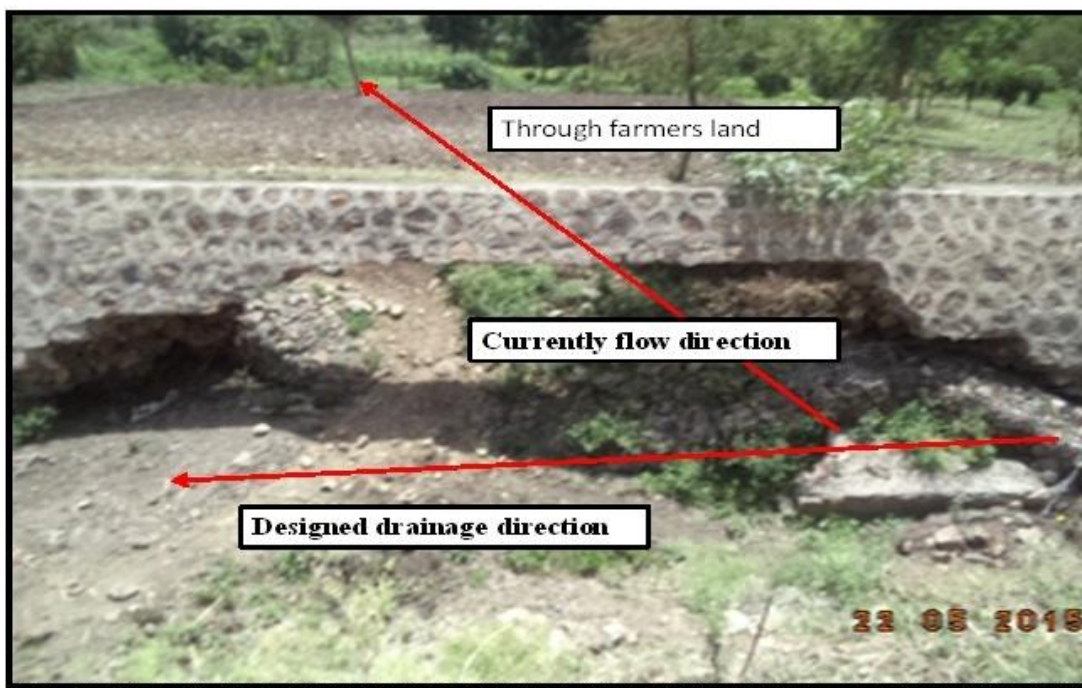
Appendix figure 7: Main canal water losses at Aloma SSI schemes (on earthen canal)



Appendix figure 8: Water losses in main canal (water transmitting flume)



Appendix figure 9: Local water control and canal breaching



Appendix figure 10: Damaged cut-off drains at Jari SSI scheme



Appendix figure 11: Flooding irrigation for potato crops at Aloma SSI scheme



Appendix figure 12: House hold survey and team of interviewers

Appendix table 28: Questionnaires for the Evaluation of Jari and Aloma Small Scale Irrigation Schemes

Zone: _____	Woreda: _____	Kebele: _____
Scheme Name: _____	Farmer's Name: _____	Location of the plot: head/mid/tail
Agro Ecology: _____	Enumerator: _____	Date: _____

1. Household characteristics and HH Resources

1.1. Household head : Male: _____ Female: _____ Age: _____ Educational Level: _____

1.2. Family size: F: _____ M: _____

i.<15yrs.....	ii. 15-65yrs	iii. >65yrs	
---------------	--------------	-------------	--

1.3. Marital status of the respondent:

i.Married	ii.Widowed	iii. Divorced	iv. Unmarried
-----------	------------	---------------	---------------

1.4. Literacy level of the household:

0= illiterate		Elementary		Diploma and above	
Read and write only		H. school complete			

2. Household Asset

2.1. What is the major occupation of the household?

i.Crop Production	ii. Livestock	iii. Vegetable	iv. Mixed farming	v. Others
-------------------	---------------	----------------	-------------------	-----------

2.2. Do you have additional incomes that supplement your major occupation? Yes/ No

2.3. If yes, what?

2.4. Total land size

<i>S.no</i>	<i>Total land owned</i>	<i>Timad</i>	<i>Total irrigated land</i>	<i>Timad</i>
1	Land under cultivation		Owen land	
2	Grazing land		Leased in	
3	Homestead		Shared in	
4	Fallow land			
Total				

2.5. How was your agricultural production for the last three years?

i. Excess for annual household consumption	ii. Sufficient for annual household consumption
iii. Sufficient for six months only	iv. Sufficient for less than six months

2.6. If your household faced food shortage, what do you think was the reason? (Rank in order of importance).

i. Land shortage		ii. Oxen shortage	
iii. Labor shortage		iv. Crop failure due to erratic rain fall	
v. Poor productivity		vi. Farm implements shortage	
vii. Others (specify).....			

2.7. How do you evaluate sufficiency of rain fall of the area for crop production?

i.Excess	ii. Sufficient	iii. Insufficient	iv. Very low
----------	----------------	-------------------	--------------

2.8. Irrigated and rain fed production practice

<i>Crops cultivated in</i>	<i>Nominal area</i>	<i>Area harvested</i>	<i>Obtained crop yield in</i>
----------------------------	---------------------	-----------------------	-------------------------------

2006/07		cultivated (ha)				2006/2007 (kg/timad)
Crops				Irrigated	Rain fed	
1	Cereals					-----kg-----q
1.1						-----kg-----q
2	Vegetables					-----kg-----q
2.1						-----kg-----q
3	Fruits	No				-----kg-----q
3.1						-----kg-----q

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

3.2. For how long do you have access to irrigation water in a year on your major irrigated plot (which month and No. of months)

1-3 months	4-6months	7-9months
Months	Months.....	Months

3.3. Major crop irrigation water requirement

S.No	Crop type (refer the previous irrigated crops)	Nominal area irrigated (ha)	Irrigation application methods	Irrigation water application frequencies (days)	Total number of irrigations	Length of growing periods	Average duration of irrigation (hrs)	Field channel discharge rate (l/s)	Variation in discharge over the duration of irrigation > 10%, 10-25%, 25-50%, >50%

3.4. Why do you prefer to grow such crops? (rank in order)

i. Better price		ii. Easy to operate		iii. Seeds availability	
iv. Good production		v. High disease tolerance		vi. Others (specify)	

3.5. Do you think the project was important in your area? Yes/No

3.6. If yes, has the use of irrigation increased your annual income? Yes/No

3.7. If yes, what is the estimated proportion of increment in the amount of income from crops compared to before the project time? %

3.8. Do you irrigate all of your irrigable land? yes / no

3.9. If not, why? Rank in order;

i. Shortage of water		ii. Low productivity		iii. poor quality of irrigation	
iv. Getting sufficient produce by rain feed agriculture		v. poor maintenance		vi. Others (specify).....	

3.10. Is there a mechanism of water pricing for irrigation users? Yes/no

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

3.12. Did you experience serious water shortages to the extent that significantly affected your yield during the last 3 years? If yes, when and what was the causes. (Water shortage, poor irrigation maintenance, over flooding of the farm and consequent erosion....)

	2005	2006	2007
Yes/No			
Causes			

3.13. Are there any problems during the application of irrigation water? yes / no

3.14. If yes, what are they? (rank them)

i. Downstream conflict		ii. Shorter time allowed for irrigation water flow	
iii. Water use administration problem		iv. Lack of maintenance	
v. Lack of operational skill/training		vi. Others.....	

3.15. Reliability (dependability) of irrigation water supply (in terms of flow rates and duration of supply).

Flow Rate	Good	Medium	Bad	Very bad
Duration of supply	Good	Medium	Bad	Very bad

3.16. Is the distribution fair?

Very fair	Fair	Unfair	Very frustrating

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

Head users	Corrupted officials/WUA	Illegal water users	Non-reliability of the water sources	Others explain

3.18. Dependability of the water deliveries to get water on arranged irrigation turns?

Good	Medium	Bad	Very bad

3.19. If the delivery is bad/very bad, explain why it is so?

Poorly functioning irrigation infrastructure	Illegal water users	Weakly organized water delivery services	Non-reliability of the water sources	Other, specify

3.20. Do you have adjustable flow control mechanism at your farm inlet to regulate water flow to your field? yes/No

3.21. If yes, what types of measuring equipments are used?

3.22. Rank the following important factors which most inhibit your irrigated production at Present.

Factors	Rank	Extent of the problems		
		Simple	Modest	Considerable

Water				
Land				
Input				
Credit				
Market				
Transport				
Crop damage				
Absence of gov't support				
Lack of skill				

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

i. Water supply availability		ii. Fixed time periods	
iii. Condition of the plant		iv. Other specify	

3.24. Do farmers have problems with the following? (Rank order according to priority)

i. Runoff loss resulting from excess irrigation water		ii. Water logging resulting from excess irrigation water	
iii. Deep percolation resulting from excess irrigation water		iv. Observable salt built-up resulting from excess irrigation water	
v. Other (specify)			

3.25. Cropping pattern (total plot size that can be irrigable)

S. No	Crop type	Nominal cultivated area in 2006/07E.C (Timad)			J	F	M	A	M	J	J	A	S	O	N	D
		Rain fed	Season 1	Season 2												

3.26. Please indicate your crop rotation for the last 3 years

Plot	Area (timad)	2005			2006			2007		
		Crop1	Crop2	Crop3	Crop1	Crop2	Crop3	Crop1	Crop2	Crop3

3.27. Production price

S. No	Crop type	Output price received in 2007 (birr/100kg)			Estimate of average output price for the last 2 years (birr/100kg)	
		Min	Max	Avg	2006	2005

3.28. Did you use chemical fertilizer in 2006/2007?

Crop type	(Yes/No)	If yes, what was the total quantity of chemical fertilizer used? (kg)	Did you use organic fertilizer? Yes/No

		Irrigated	Rain fed	Irrigated	Rain fed	
				UREA..... DAP....	UREA....DAP...	

3.29. What was the price for chemical fertilizer? (birr/50kg) UREA..... DAP.....

3.30. Improved seed;

	Crop type	3.30. Did you use improved seed? Yes/No	3.31. What was the total quantity of seed/tuber used per timad (whether purchased or own)? kg	3.32. What was the price for seed (whether purchased or own)? Birr/kg

3.31. Pesticides;

	Crop type	3.33. Did you use pesticides? Yes/No	3.34. If yes		3.35. What was the price pesticide? Birr/liter
			Name of pesticide	Quantity, liters	

3.36. How many kilometers far away the market and your house from the irrigation scheme?
.....andrespectively.

3.37. How do you feel the farm gate prices of your major irrigated crops compared those in nearby larger market centers?

i.Satisfactory	ii. Low	iii. Very low
----------------	---------	---------------

3.38. Cost elements and value added of the agricultural production process.

S.No	Cost item	Total ETB/year for land under irrigation
1	Cost of land	
2	Cost of services (rent of farm equipment/pump maintenance)	
3	Cost of inputs, fertilizers, seeds, pesticides	
4	Payment for irrigation services and O & M	
5	Wage of casual laborer	
6	Wage of permanent worker	
7	Other costs (Explain)	
8	Interest paid on loan	

3. **Project Evaluation**

4.1. Who initiate the idea of constructing the structures?

i. Local people	ii. DA	iii. Project staff	iv. Others
-----------------	--------	--------------------	------------

4.2. If it is not the local people, have you agreed about the construction of the structures? Yes/No
WHY?

4.3. Did you agreed on the project/diversion site? Yes/No

4.4. If no, what was your opinion about the site of the diversion?

4.5. Do you see any structural failure? Yes/No

4.6. If yes, which structures?

Type of structure	The head work	The canals	Other structures (indicate)
Causes			

4.7. Explain the type of contribution you made for the project during construction?

i. Money, (Amount, birr/year)	ii. Labor, (No. of labor days per year)	iii. material	iv. land
v. By rule without payment (mass mobilization)	vi. 1&2	vii. 1&2&3	viii. 1&2&3&4
ix. 1&2&3&4&5	X. others.....		

5. **Institutional supports**

5.1. Have you ever visited by an extension agent? Yes / No

5.2. If yes, during which operation?

i. Land preparation	ii. Planting/transplanting	iii. Weeding
iv. Applying agro chemicals	v. Watering	Vi. Harvesting

5.3. What kind of institutional support do you need in relation to the scheme?

i. Organization and management	ii. Maintenance
iii. Increase the scheme's capacity	iv. Others.....

6. **Organizations**

6.1. Is there water users association in your locality? Yes/ No

6.2. If you have an organization, what is its organization and management function?

i. prepare operation plan	ii. operation of irrigation system	iii. Equitable distribution of irrigation water	iv. prevent wastage of water
v. regular inspection of irrigation structures	vi. preparation and implementation of maintenance plan	vii. All of these	viii. None of these

6.3. Are you a member of water users association? Yes /No

6.4. If you are the member of WUAs, what benefits do you get from being a member?

i. Irrigation water on program basis	ii. Economic water use
iii. Adapt social accountability and responsibility	iv. All

6.5. As a member of WUA what is your contribution for the sustenance of the scheme?

i. Cost sharing	ii. Labor contribution	iii. Others
-----------------	------------------------	-------------

6.6. Generally, how do you perceive the overall contribution of WUA to the scheme functioning and sustenance?

i. It has positive contribution	ii. No contribution at all	iii. Not known
---------------------------------	----------------------------	----------------

6.7. What do you feel about performance of WUA committees in the management of water distribution in the scheme? Yes / No

i. Enough water is not received (adequacy)	ii. Water distribution is unfair (equity)
--	---

iv. Water is not received when needed (timeliness)		
--	--	--

6.8. What is the major management problems related to water distribution in the irrigation system (if applicable)? Yes/ No

i. Sanctions not imposed against illegal water users	ii. Poor coordination of water distribution by WUAs committee
iii. Rotation does not accomplish equality	iv. Rotations are not strictly implemented

6.9. Do think the water allocation and distribution (scheduling) adopted by the organization (in use) at your scheme is fair and unbiased.

- a. Yes b. No c. No idea

6.10. Are internal regulations of the organization acceptable to you?

a. yes	b. No	c. Don't mind
--------	-------	---------------

6.11. In your opinion, have your internal by-laws been enforced (in relation to water allocation/distribution/conflict management and fees)? Yes /No

6.12. If no to the previous question, what are the major reasons? Please rank the following.

Number them from 1=most important, to 3= least important

i. Users do not respect the decisions of the WUAs committee		ii. Lack of external support in water and conflict management	
iii. WUAs committee members are reluctant			

6.13. If WUAs committee members are reluctant, why it is so? Response: Yes /No

i. Some members do not respect their decisions (resistance)		ii. Lack of adequate support from local governance and the irrigation agency	
iii. They have no incentive		iv. Others, specify	

6.14. Have you ever faced any conflict over irrigation water? Yes / No

6.15. If your answer is yes, what are the causes?

i. Water theft	ii. Competition due to increasing number of water users
iii. Water scarcity	iv. Lack of proper control of water distribution
v. Others, specify	

6.16. How do you feel about the involvement of females in decision making in the irrigation organization?

i. None	ii. Insignificant	iii. Fair
---------	-------------------	-----------

7. **Sustainability of the project**

7.1. Do you feel that the irrigation scheme belongs to you? Yes No

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

i. to the community	ii. to the NGOs
iii. to the government	iv. any combination of the above

7.3. Have you ever participated in maintenance of the irrigation scheme? Yes /No

If yes,

Labor , (No. of labor days per year)	Maintenance fee,(Amount, birr/year)

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

i.It is not my responsibility	ii. I do not know how to do it
iii. Others (specify	

7.5. How frequently is routine maintenance (cleaning) of your closest infrastructure (canals and structures) take place per year by the initiative of the irrigation organization?

Once	Twice	Three times	>three times	None

7.6. The maintenance condition of your irrigation infrastructure?

Good	Medium	bad	Very bad

Appendix table 29: Focus Group discussion checklist

Participants;

- Chair man of WUA (organization) (key informant)
- Vice chairman of WUA (organization) (key informant)
- District agricultural bureau irrigation/agronomy expert (key informant)
- Member of the watershed/sub watershed water allocation party (key informant)
- Water users selected by stratified proportional random sampling for focus group discussion (head, middle, and tail users)

Section1. Irrigated agriculture production

- 1.1. What is the major objective attached to irrigation in the area, food security, cash income or mixed? And why? (Group discussion)
- 1.2. What is the size of total service area of the irrigation scheme? How does it fluctuate from season to season and what is the cause? (Group discussion)
- 1.3. Similarities and differences in cropping patterns and rotations between farmers in general? Reasons for variations? (Group discussion)
- 1.4. Fertilizers availability, timing and price affordability at the scheme in general? (Key informant interview and group discussion)
- 1.5. How good is land and water productivity in this scheme? Explain by comparing with experiences in other schemes? /head, middle or tail/. What are the main constraints for production and productivity? (Key informant interview and group discussion)
- 1.6. Does the economic output in the scheme in general enable farmers cover all the irrigation and inputs fees? How justifiable is irrigated agriculture at this scheme economically? (Key informant interview and group discussion)
- 1.7. What are the prospects and potentials for improvement of agricultural productivity at the scheme? How could this be achieved in your opinion? (Key informant interview and group discussion)

Section2. Irrigation scheme (infrastructure and water distribution)

- 2.1. Your opinion on the reliability and sustainability of irrigation water resource? Its seasonal fluctuation? (Key informant interview and group discussion)
- 2.2. How did water diversion to the scheme at the head work behave during the past few years in terms of volume of water delivery? (Key informant interview and group discussion)
- 2.3. Existence of competitions for water at watershed levels between upstream and downstream users? Causes and impacts? (Key informant interview and group discussion)
- 2.4. Is water distribution reliable throughout the scheme (head, middle, tail)? If not what are the cause and impacts? (Key informant interview and group discussion)
- 2.5. Is poor watershed management a concern to the water distribution in the scheme? Impacts of erosion/sedimentation? (Key informant interview and group discussion)
- 2.6. Are there water losses due to seepage, leakage, over topping etc? Why was it not possible to reduce it? What are the impacts? (Key informant interview and group discussion)
- 2.7. Are conditions of flow control and canal infrastructure in the scheme adequate for equitable and reliable water distribution and delivery in the scheme? (Key informant interview and group discussion)
- 2.8. How is water distribution effected at the main and tertiary levels? Rotational or continuous? How irrigation schedules are (turns) determined? How do you deal with variations needed during different growing stages of crops? (Key informant interview and group discussion)
- 2.9. Are irrigation schedules well discussed and agreed upon by the farmers before the start of irrigation seasons? Is there flexibility for sensitive crop types and growing stages? (Key informant interview)

Section3. Organization and socio economic environment

- 3.1. What kind of establishment do you have for management, operation, and maintenance the irrigation scheme? When was it established? (Key informant interview and group discussion)
- 3.2. What are the conditions for membership, mandatory or optional? (Key informant interview and group discussion)
- 3.3. If optional, how serious are the unauthorized access to irrigation services? How do you deal with illegal water uses (free riding)? (Key informant interview and group discussion)
- 3.4. Capability of the WUA (organization) to discharge its duties? What are the major limitations? (Key informant interview and group discussion)
- 3.5. How is the willingness of farmers to pay irrigation water fees and contribute to annual O&M? (Group discussion)
- 3.6. What are mechanisms for assessing irrigation fees? How effective is the WUA in collection of fees owed? What are the constraints? (Key informant interview and group discussion)
- 3.7. How well are the internal regulations respected by farmers and how effective is the WUA to enforce them? (Key informant interview and group discussion)

- 3.8. How does the organization deal with conflicts between farmers and the organizations? (Key informant interview and group discussion)
- 3.9. What are the current trends of development in the area in general, and the scheme or system in particular? (Group discussion)
- 3.10. Typical structure of the WUA (Group discussion)