Comparative Performance Assessment of two Small Scale Irrigation Scheme in West Harerghe

By

Nade Nuru

A Thesis Submitted to

The department of Water Resource Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Water Resource Engineering (Specialization in Irrigation Engineering)

Office of Graduate Studies

Adama Science and Technology University

Adama,Ethiopia

December, 2018

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THESIS RESEARCH APPROVAL SHEET

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DECLARATION

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

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ACKNOWLEDGEMENT

I feel deeply obligated to express my greater appreciation to my advisor **Dr.Mekonen Ayana** for his irreplaceable advice and specialized guidance from the start of proposal writing to the end of my thesis writing, as without his assistance this work would have not been successful. Many thanks go to Adama science and Technology University for offering the study opportunity for me. I would like to thank my parents and friends for their constant and unlimited encouragement, concern, understanding and moral support.

Special thanks are due to my best friends Ararso Mohammed and Dereje Kafyalew staff of west Harerghe irrigation development authority office in Chiro for their encouragement and help for the accomplishment of this study. Acknowledgment is also expressed to the Oda Bultum and Gamachis woreda irrigation office staff and woreda agricultural department for offering the required data for this study.

TABLE OF CONTES

THESIS RESEARCH APPROVAL SHEET I

DECLARATION II

ACKNOWLEDGEMENT III

LIST OF TABLE VI

LIST OF FIGURES VII

LIST OF ACRONYMS VIII

ABSTRACT IX

1 INTRODUCTION 1

1.1 Background 1

1.2 Statement of problem 3
1.3 Objective of the study 4
1.3.1 General objective 4
1.3.2 Specific objective 4
1.4 Significance of the research 4
1.5 Scope of the study 4

2 LITERATURE REVIEW 5

2.1 Concepts of irrigation system performance 5
2.2 Purposes of performance assessments 6
2.3Framework for performance assessment 8
2.4 Irrigation scheme performance indicator 9
2.5Irrigation scheme performance in Ethiopia 12
2.6 Crop-water requirements, irrigation schedules and depths 14
2.7 Performance gaps existing in irrigation management 14
2.8 Comparative performance indicators 15
2.8.1 Indicators of Irrigated Agricultural Output 16
2.8.2 Water supply and financial Comparative Indicators 16
2.8.3 Purposes of comparative performance indicators 17

3 MATERIAL AND METHOD 18

3.1. Description of the Study Area 18

3.1.1 Homacho sogido 18
3.1.2 Jawis scheme 21
3.2 Data Collection 23
3.2.1 Primary data collection 23
3.2.2 Secondary data collection 24
3.3 Data analysis method 24
3.3.1 Comparative performance indicators. 25
3.3.2 Physicalsustainability indicator 27
3.3.3 Irrigation demand and crop water demand determination 28
4. RESULT AND DISCUSSION 31
4.1. Crop and irrigation requirement 31
4.2. Performance measurement 33
4.2.1 Physical performance indicator 33
4.2.2. Water supply performances 35
4.2.3. Production performances 38
4.3. Evaluation of performance gaps 42
4.4. Improvement options 44
5 CONCLUSION AND RECOMMENDATION 45
5.1 Conclusion 45
5.2 Recommendation 46
7 APPENDICES 52
Appendix-A Climatic, Rainfall, crop data and Parshall flume 52

LIST OF TABLE

Table 3-1 Land use patterns of the Gamechis woreda-- 19

Table3-2 Description of the parameter of the study area-- 22

Table 4-1 Result of CWR and IR of the Jawis irrigation scheme for two seasons in the year 2010E.C. 31

Table 4-2 Result of CWR and IR of Homacho irrigation scheme for two cropping season in the year 2010E.C.. 32

Table 4-3 Result of the NCWR and NIWR of the Jawis for the two irrigated seasons in the year of the study (2010E.C).. 32

Table 4-4 Result of the NCWR and NIWR of the Homacho for the two irrigated seasons in the year of the study (2010E.C.)... 33

Table 4-5 Summary of the command area and presently irrigated area and initially irrigated area of Jawis and Homacho scheme in 2010E.C... 34

Table 4-6 Measured values of the canal flow by using standard three inch parshall flume. 36

Table 4-7 Result of some parameter for the two irrigation scheme for the year 2010E.C. 36

Table 4-8 Peak IR of the Homacho and Jawis irrigation scheme. 37

Table 4-9 Total yield and land coverage of Jawis and Homacho irrigation scheme for year 2009 E.C. 38

Table 4-10 Total yield and cropping pattern and land coverage of Jawis and Homacho irrigation scheme for the year 2010 E.C. 39

Table 4-11 Command area, cropping area, irrigation water and yield of the Jawis and Homacho irrigation scheme.. 40

Table 4-12 Summary of the calculated agricultural indicator for the Jawis and Homacho scheme in the year 2009 and 2010E.C.. 41

LIST OF FIGURES

Figure 3-1 Headwork of Homacho sogido irrigation scheme 21

Figure 3-2 Headwork of Jawis irrigation scheme 22

Figure 3-3 Location of Jawis and Homacho scheme with their headwork site. 18

Figure 3-4 Field measurement of canal flow 24

Figure 4-1 Pysical indicator of the Homacho and Jawis irrigation scheme 42

Figure 4-2 Water delivery indicator of the Homacho and Jawis irrigation scheme. 42

Figure 4-3 Land and water productivity indicator of Homacho and Jawis indicator. 43

LIST OF ACRONYMS

a.m.s.l	Above Mean Sea Level
ARIS	Annual relative irrigation supply
ARWS	Annual relative water supply
CWR	Crop water requirement
DA	Development agent
FAO	Food and agricultural organization of the united nation
HHH	House hold head
IR	Irrigation requirement
IWMI	International Water Management Institute
NCWR	Net crop water requirement
NIR	Net irrigation requirement
OPUCA	Output per unit command area
OPUIA	Output per unit irrigated area
OPUWC	Output per unit water consumed
OPUWS	Output per unit water supply
PA	Peasant association
SGVP	Standardized Gross value of production
SSI	Small scale irrigation
US$	United States dollar
WDC	Water delivery capacity
WHIDA	West Harerghe irrigation development authority

ABSTRACT

This research was conducted to assess and compare the performance of two small scale irrigation schemes by using comparative indicator andto determine the level of performances of the schemes and identify performance gaps and improvement measures. This was done by selecting two irrigation schemes in the West Harerghe: Homacho sogido and Jawis irrigation scheme due to the availability of data. Based on the collected primary and secondary data seven (7) comparative indicators from the nine indicators indicated by IWMI and three physical indicators were selected for this study. The collected data are measurement of canal capacity, total yields, farm gate prices of irrigated crops, area irrigated per crop per season, crop types, production per season or per year, cropping pattern, irrigable land, currently irrigated land and initially irrigated land. The indicators used are irrigation ratio, cropping intensity, sustainability of irrigated land, output per cropped area, output per command area, and output per irrigation diverted, output per water consumed, relative water supply, relative irrigation supply, and water delivery capacity. The major crops grown in both schemes are Chat, Cabbage, Sorghum, Maize, Tomato, Soybean and Onion. The result of the analysis express that irrigation ratio, cropping intensity and sustainability of irrigated land of Jawis scheme is 100%, 146% and 100% respectively and for Homacho sogido scheme is 100%, 159% and 119% respectively. The ratio of ARWS, ARIS and WDC for jawis scheme are 1.01, 3.83 and 1.9, for Homacho sogido scheme are 1.3, 3.96 and 3.33. The four agricultural indicators; output per cropped area, output per command area, output per water consumed and output per unit water supply are in the order of 16843.4 birr/ha, 19730.86 birr/ha, 2.23 birr/m^3, 4.24birr/$m^3$and 24304.5birr/ha, 38692.8 birr/ha, 3.29birr/m^3 and 4.28birr/m^3 for Jawis and Homacho sogido, respectively. The result obtained shows that irrigated areas at Jawis was found to be neither contracting nor expanding while it was expanding at Homacho due to more land productivity and water delivery capacity of the canal to the irrigated area as compared to Jawis scheme. Excessive annual irrigation water was supplied in both scheme due to lack of knowledge on water diversion by farmer based on crop water demand. This can be improved through training of farmer to balance crop water demand and water diversion. Homacho irrigation scheme could be benchmarked in the zone for water productivity and land productivity.

Key words: Comparative indicator, performance assessment, Small scale irrigation scheme.

1 INTRODUCTION

1.1 Background

For agricultural production, water is a valuable resource. Shortage and abuse of water resources pose extreme and growing pressures to life and sustainable development. Growing yields and fulfilling food production depends mainlyon irrigation in countries where water is a warning factor to agriculture. Irrigation is the supply of water to agricultural crops by artificial means, designed to allow farming in arid areas and to counterbalance the impact of drought in semi-arid area. Water use and opposition among different users has been growing at more than twice the rate of population increase over the last century, leading to often conflicts among them (Imbenzi J.et al, 2014). For instance, water use for irrigation accounts forabout 70% of all freshwater worldwide and irrigation has beenranked as one of the activities that utilize a large portion of fresh water in many countries. Many large-scale irrigation schemes in least developed countries are out of the reach of smallholder farmers (zeleke A., 2015). However, in these countries, small-scale irrigation is the primarydonor to food security and developments in rural livelihoods.

There are numerous reasons for encouraging small-scale irrigation schemes (Tafesse, 2003) including: lower investment costs, ease of maintenance, more flexible manage of water by the users, possibility of reaching remote and poor farmers, possibility of water management by the water users, less negative environmental impacts.Nevertheless, many small-scale irrigation schemes in least developed countries are often characterized by low land and water productivity, poor physical infrastructure, less reliable water supply and unsustainable asset management. If these factors discouragement the benefit of these schemes are addressed, small-scale irrigation schemes can play a big role for ensuring food security for the vast smallholder communities in these countries (Zeleke A., 2014).

The potential irrigable land of the country is estimated to be about 3.7 million hectares (and some studies reveal that it can reach up to 4.3 million hectares) and only about 10-12% of the total potential is currently under production using traditional and modern irrigation schemes(Ministry of Agriculture, 2011). The Ethiopian government is began development of numerous new irrigation projects, yet the performance of currentirrigation schemes are given less attention.The effective use of both rainfall and irrigation water are interdependent, yet we often only examine the effective use of irrigation water. With growing population and therefore demand for food, maintainable production in irrigated agriculture shouldbe attained through development of new irrigation project and/or improvement of the performance of the existing schemes. In awareness of both the benefit and risks assessment and evaluation of irrigation schemes performance has now become a principal importance not only to point out where the problem lies but additionally helps to find alternatives that may be both active and achievable in improving system performance.

Water supplies at any given place are often poorly matched to crop needs, highly variable in both timing and discharge, and are, sometimes, of increasingly poor quality (Cakmak B., 2004).But improving irrigation system performance is becoming significant because the overallperformance of many irrigation systems is significantly below their potential due to one of shortcomings such as poor planning, operation and maintenance, and overall poor water management practices (Cakmak B., 2004).

Improving the performance of irrigation schemes through a number of involvementsis regarded as a key issue for addressing the need for increased productivity of irrigated lands under pressure on water resources. Many irrigation schemes, specifically in least developed and emerging countries, are characterized by a low level of overall performance. Areas of poor irrigation performance include mismatch of supplies and demands, insufficient maintenance, insufficient manual operation of structures, operational leakages and field losses, poor irrigation service, water loggingand salinization (Zeleke A., 2014).Improving the performance of irrigation systems requires setting some relevant criteria for performance and identifying indicators which can enhance the performance level (Zeleke. et al,2012).

In addition to internal performance indicator to evaluate the performance of the scheme, the International Water Management Institute (IWMI) suggests using minimum set of comparativeindicators to assess hydrological, agronomic, economic and financial performance of irrigation system. The assessment can be done to obtain the level of service pertaining to operation, strategic, diagnostic and comparative, that is relative to other schemes in terms of management environments, and for evaluation of the impacts of management interventions(Gomo.et al, 2013).It can also use to assess the trend in performance of specific scheme over time or for the purpose of benchmarking with other schemes exhibiting good performance

The majority of our people are settled in rural area, and the largest amount of income of the country is obtained from agriculture: Thus from development context to bring change the livelihood of the rural people and the overall development of the nation, need to improve our agricultural sector (WHIDA, 2010). Improvement of agricultural productivity can be caused among others by using farming lands to intensive and continual practices irrespective of seasons and affirmative land use methods.The Oromia irrigation Development Authority office is responsible organization to make a great role in making sustainable and reliable agriculture though the development of modern and improved irrigation schemes in Eastern and Western Hararghe zone of the Oromia region.

Besides the poor performance of irrigation scheme in the country the performance assessment of small-scale irrigation systems is not common in the Oromia region especially West Haraghe zone. Hence, this study attempts to introduce the concept of comparative performance indicators in order to assess the performance of two small-scale irrigation scheme in the West Harerghe.

1.2 Statement of problem

Water is a valuable resource for agricultural production. Scarcity and misuse of water pose a serious and growing threat to life and sustainable development. As water is the limiting factor in most of the world, increasing yields and sustaining food production depend mainly on irrigation. Therefore, protection and development of water resources are crucial for irrigation facilities. The Performance of many irrigation systems is significantly below their potential due to a number of shortcomings, including poor design, construction, operation and maintenance.

The head regulator and the sluice gate built on the weir are not providing the proper function.

With growing population and demand forfood, sustainable production increases fromirrigated agriculture must be achieved.Withinadequate freshwater and land resources, andincreasing competition for these resources,irrigated agriculture worldwide must improve its utilization of these resources.Performance assessment is used to identify the present rank of the scheme with respect to the selected indicators and help to identify ‘why the scheme is performing so’ which in turn suggest means of improvement.Irrigation projects are widely studied, planed and implemented throughout Ethiopia. However, no attention is given to the monitoring and evaluation of the performance of already established irrigation schemes. Whether traditional or modern, public agency or community managed many of the existing irrigation systems are failing in their physical structures, operation and management(Mekonen and Seleshi, 2006).Irrigation schemes in the west Harerghe is poor management of irrigation systems are compounded by competition for water access by crop, livestock, small holders

There were no any previous studies done on the performance of small scale irrigation scheme in the Zoneso this research work is aimed to assess the comparative performance of the two small scale irrigation scheme in West Harerghe using comparative indicator.

1.3 Objective of the study

1.3.1 General objective

The general objective of this study is to assess and compare the performance of two small scale irrigation schemes by using comparative indicator.

1.3.2 Specific objective

- to determine the level of existing performances of the schemes.
- to compare the performances and identify performance gaps.
- to identify improvement measures.

1.4 Significance of the research

This study presents the comparative performance of the two small scale irrigation scheme in West HarergheThus, to assess the achievements of utilization of the available resources such as: land and water at the scheme by using comparative indicator to meet rising challenges; increasing demand for irrigation to meet the increasing food demands of the community those use the scheme so that the contribution of this study is very essential and helpfulfor the designers, irrigation engineers and decision makers to take appropriate decisions on performance of the scheme.

1.5 Scope of the study

The scope of this research werelimited to assess and compare theperformance of two community managed small scale irrigation scheme by using comparative indicator and to determine the level of performances of the scheme and compare the two schemethroughperformance assessment. In addition the out puts of this study are believe to evaluate the problems of the two irrigation schemes and show future routefor planning, design and operation of irrigation projects in the study area.

2 LITERATURE REVIEW

2.1 Concepts of irrigation system performance

Performance terms measure how close an irrigation event is to an ideal one. Anideal or a reference irrigation is one that can apply the right amount of water over the entire area of interest without loss.Evaluation is a process of establishing a worth of something. Performance evaluation is the systematic analysis of an irrigation system and/or management based on measurements taken under field conditions and practices normally used and comparing the same with an ideal one(.Ali,2010).Traditionally, irrigation audits are conducted to evaluate the performance of existing irrigation systems. A full irrigation audit involves an assessment of the water source characteristics, pumping, distribution system, storage, and in-field application systems. However, audits are also conducted on several components of on-farmirrigation system.

Irrigation systems are members of a wide class of human systems whose existence and performance are significantly based on human behavior. Further- more, most irrigation systems are characterized by the existence of some central coordinating organization accountable for making and enforcing key decisions affecting the acquisition and distribution subsystems.

Typically, this organization is a formally-structured organization, although in small irrigation systems the agency may be very informal. The performance of an irrigation system is strongly influenced by means of the behavior of this coordinating agency (LESLIE E.et al, 1990).

The performance of irrigation system is represented by its measured degrees of accomplishments in terms of one, or several, parameters which are selected as indicator of the system's goal. The exploitation and utilization of water for irrigation need that there are periodic assessments of its utility and effectivity of use. This concern with performance inside the irrigation sector is growing as pressure grows on water resources in all parts of the world, and as concerns increase concerning the sustainability of irrigated agriculture systems (Murry-Rust. et al, 1993). Any organization requires comments on the management of resources and the end result in terms of improved output.

During this century there has been a dramatic extend in the place irrigated. Most of this growth has happened through capital investments in infrastructure for the capture, storage and distribution of water, and in the conversion of rain-fed areas into irrigable land. This kind of development has created a number of groups who have a direct concern on the performance of the irrigation system: investors, policymakers, planners, managers and users (Murray-Rust. et al, 1993). Each of these groups has to be able to determine the effectiveness of the systems in which it has a stake. To do this these groups require not only primary information about the inputs and outputs of the system, however additionally a framework within which this information can be processed and evaluated.

2.2 Purposes of performance assessments

The purpose of performance assessment is to measure, through consistently applied standards, numerous factors that indicate either by comparison across systems whether a system is performing 'well' or 'badly' in a relative sense or by a system-specific analysis to see how the system is functioning in relation to its own objectives(.Ali,2010). The specific purposes of performance assessment according to outer are:to improve irrigation performance, to improve management process, to improve sustainability of irrigated agriculture, Improved quality of activities, Improved ability of the managers to manage the system, Savings of water and energy, Ensure maximum production/benefit and minimum cost.

Repeated monitoring of the performance of irrigation systems will support to differentiatewhether the targets and objectives are being met or not. It also provides system managers, farmers, policy makers a better understanding of how a system operates. It helps to identify the strengths and weaknesses, consequently alternatives that may be both operative and possible in improving system performance to accomplish maximum efficiency (Mintesinot. et.al, 2005).

The non-involvement of farmers on the management of the scheme, lack of repairs, and maintenance of the infrastructure, ineffective irrigation committee, incorrect irrigation frequencies, and lack of marketing strategies were some of the major reasons identified for the inability of the scheme to fulfill its primary objectives(Kotei. et al, 2015).

Performance assessments of irrigation schemes has now a principal importance to point out where the problems lies and to identify options that may be both operative and achievable in improving irrigation system performance(Mintesinot. Et al.,2005). An ideal irrigation is one that can apply the exact amount of water over the wholearea of interest without loss (Zerihun et al., 1997). Then, various performance evaluation terms are used to measure how the irrigation system is close to the ideal one. The nature of an evaluation of a system's performance will depend on the purpose for which the evaluation is being conducted. In some instances periodic assessments are undertaken to assess the operational status of the system and to recommend adjustments. In different cases, the assessments are intentionally organized to regulate the behavior of certain actors in the system. In these cases, the motive of the assessment is to concurrently modify and reveal behavior.The reason of any performance assessment should be really specified, because assessments suitable for one purpose may be quite unsuitable for other (LESLIEetal, 1990).

In general, three broad kinds of performance assessments can be recognized according to (LESLIE E.et al, 1990). Such as:

Operational performance monitoring, intervention assessment, and account- ability assessment. These differ in terms of the audience for the results of the assessment, the timeframe of the assessment, the time requirements for processing field data, and the standards employed in making judgments.

Operational performance monitoring

Managers of an irrigation agency need a continual flow of current information about the system's performance as an input to their daily operational decisions. Performance information is needed both about internal processes and their resulting intermediate outputs, and about the final outputs of the system. The useful lifetime of this information in system control applications is counted in hours and days rather than weeks or months. Managers are likely to be concerned primarily with the intermediate and final outputs of irrigation, with in- puts being taken more-or-less as given. In some cases, managers may aggregate this information into a longer period format (such as an agricultural season) for retrospective analysis, in which case they may also be concerned with evaluating outputs in relation to the amount of inputs used.

Intervention assessments

A desire to improve some aspect of irrigation performance underlies a wide variety of irrigation system interventions made by managers and government agencies. These interventions may range from modest changes in water distribution procedures to major rehabilitation of physical facilities. Many individuals and organizations - including government planning agencies, external donor agencies, managers within an irrigation agency, and professional irrigation researchers - will want both ex ante assessments to evaluate the desirability of or need for a proposed intervention, and ex-post assessments to assess the results of the intervention. Such assessments generally require data for one or more complete seasons. Lags between the initiation of an intervention and the resulting changes in performance may make it necessary for ex post assessments to cover a multi-year period. Annual variability in conditions may also make it prudent for a study designed to evaluate an intervention to incorporate data from several years into the analysis.

2.3Framework for performance assessment

A common process of performance assessment cannot be only output-oriented. To be sure, outputs are important to the assessment, but they are used to determine opportunities for improvement within the entire management cycle, not only in raising the level of outputs as a single objective ((Murry-Rust etal, 1993).At the start, it is clear that the portion of management control, the process by which the achievement of the various management functions of planning, organizing, and implementing is reviewed and adjusted, relies on having good information((Murry-Rust etal, 1993).

Irrigation system performance assessment needs a framework to sufficiently guide the work and for the stakeholders to effectively use the consequences from performance assessment. The purpose of the framework is to form a linking between frequent actions in such a way as to provide a learning experience for the manager that allows things to be done better in each successive iteration (Bos.et al) The framework defines why the performance assessment is needed, what data are required, what methods of analysis will be used, who is the performance assessment for, etc. (Bos. et al., 2004). Without anappropriate framework the performance assessment programme may fail to collect the required data, and may not provide the required information and understanding to theuser. Performance assessment is based on collection, analysis and interpretation of data associated to irrigation management and irrigation service delivery.

Performance assessment of irrigation management can be viewed from two perspectives according to (Zeleke, 2015):

Operational performance and strategic performance. Operational performance evaluation help irrigation management to address the question ‘Am I doing things right?’ while strategic performance assessment addresses the question ‘Am I doing the right thing’? However, before one can start with the actual data collection, at least the following issues would have to be addressed: the need for assessment; the overall objective; specific objectives; whom is the assessment for?

The need outlines the rationale of the performance assessment or its purpose. The need in general would have to be addressed in a broader context instead of a specific and a single purpose. Performance evaluation needs to attain an objective in a wider sense, which might be of interest to one or more stakeholders in the sector. Hence, next to the need, the general objective has to be obviously defined. In order to attain the overall objective, it has to be divided into specific objectives. Specific objectives allowone to deal with smaller problems, whose cumulative would make up the bigger picture of the problem. The information derived from irrigation performance assessment could be of primary importance to one or more stakeholders in the sector; for instance researchers (scientific community), government, the scheme management, water user associations, farmers, funding agency, etc.

2.4 Irrigation scheme performance indicator

An indicator describes the level of actual success in respect of one of the objective of irrigation. Indicators are used to simplify the otherwise complex internal and external factors affecting the performance of irrigated agricultural systems. Given the good operation and management of irrigation, it is believed that the greater the number of irrigation projects that are functioning, the larger will be the number of beneficiaries and the positive impact on household livelihoods (Mekonen and Awulachew, 2009).

An irrigation system is a set of physical and institutional componentsengaged to acquire water from a naturally concentrated sources, to facilitate and control the movement of the water from its source to the root zone of land devoted to the production of agricultural crops (Small and Svendsen, 1990). A well operated and maintained irrigation system delivers, in timely fashion, an adequate amount of water to the point of use. Indicators, used to measure the adequacy and efficiency of water delivery, are described below:

a) Annual relative water supply (ARWS): This relates the total volume of water applied (irrigation water plus total rainfall) to the volume of water required by the crops during the period.

b) Annual relative irrigation supply (ARIS): This is the ratio of total volume of irrigation water delivered to the volume of irrigation water demanded (net irrigation requirement, i.e. crop evapotranspiration minus effective rainfall).

c) Water delivery ratio (WDR): This relates the amount of water actually delivered to the scheme versus amount of water needed to be delivered, i.e. total water supplied to the scheme divided by gross irrigation water requirement. The later was estimated by considering 65% irrigation efficiency.

d) Conveyance efficiency (Ec): This is the total amount of water flowing into a canal system at a point divided by the amount of water reaching a certain distance downstream of the previous point. It measures the efficiency of the canal system to convey water and shows the amount of water loss over a given travel distance. Ec was measured using current meter and floating methods in which the water flow velocity in the known cross-sectional areas of the canal system was measured and discharge was calculated as the product of velocity and canal cross-sectional area.

Output performance indicators. The final output of irrigated agriculture is crop production which can be expressed in terms of productivity, i.e. yield in tones or its monetary value in US$ per unit of land and water resources used. The following indicators were used to measure the output performances:

i. Output per harvested area: is the amount of yield in tons or its monetary value in US obtained per units of harvested land.

ii. Output per water supplied: is expressed as the monetary values in US$ earned per units of water supplied in m3. With this indicator it is possible to compare the productivity of different schemes and crops.

The physical indicator used for assessing the development of irrigated scheme.Lower values of this indicator would implya reduction of agricultural lands which were initially irrigated; and hence, indicate the contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated area and would imply more sustainable irrigation (Zeleke, et al., 2012). Activities of irrigation schemes start at the point of water supply head-work or pump. Effects of irrigation are not limited to the field but also incorporate to the socioeconomic conditions of the target audience. In general, a set of indicators are used for assessing the performance of an irrigation scheme. No single indicator is satisfactory for all descriptive purposes and several indicators can give an overall picture of the irrigation project (Ali, 2010).

For convenience in understanding and application, the indicators can be grouped as: Engineering indicator, Field water use indicator, Crop and water productivity and acreage, Socioeconomic

Engineering Indicators

Engineering indicators are those which are related to pump, water headwork, water supply, water conveyance system, and energy use. Indicator under engineering category according to (Sarma and Rao, 1997; Ali, 2001) include:Pumping plant efficiency, Headworks efficiency, Water conveyance efficiency, Water delivery performance, system efficiency (or overall efficiency), Equity of water delivery, Channel density, Water supply – requirement ratio, Water availability and shortage, Energy use efficiency

Field Water Use Indicators

These indicators concern the efficiency of on-farm water application and the uniformity of water distribution along the irrigated field. Indicators under this category are:On-farm water loss, Deep percolation fraction/deep percolation ratio, Runoff fraction/tail water ratio, Water application efficiency, Storage efficiency/water requirement efficiency, and Application efficiency of low quarter, Distribution efficiency or uniformity, Low-quarter distribution uniformity.

Crop and Water Productivity and Acreage

Indicators under this category are:Area irrigated, Irrigation intensity, Duty of discharge/supply water, Crop productivity (Yield rate), Water productivity, Irrigation water productivity

Socioeconomic Indicators

In some cases, cost–benefit or social uplift and social acceptance aspects are measured. These are called socioeconomic indicators. Indicators under this category include: Irrigation benefit–cost ratio, Cost per unit production, Irrigation cost per unit area.

2.5Irrigation scheme performance in Ethiopia

The irrigation scheme refers to the infrastructure for water acquisition and distribution.Irrigation schemes in Ethiopia are categorized on the basis of: the size of command area, technology used and management system. Based on the command area classification, they are classified as small (less than 200 ha), medium (200 to 3000 ha) and large scale (over 3000 ha) (Awulachew et al., 2005; MoWR, 2002).The small-scale irrigation schemes are further classified into two major categories such asmodern and traditional schemes. Modern schemes usually have stable or improved water diversion structures. Traditional schemes have no stable diversion structures and are rebuilt every year from local materials by farmers themselves. The technological classification divides schemes according to the differences in the technology used to control and divert water. These influence water availability, efficiency of water use, and operation and maintenance costs. The third classification takes into account the management system, namely traditional, modern, public and private (Werfring, 2004).

The current irrigation development in Ethiopia is about 0.7 Mha, and the performance of the existing schemes is not well understood (Seleshi and Mokenen, 2011). As the country is planning to enlarge irrigated agriculture in the future, it will be useful to review existing performance and to identify areas for interventions that help revitalize underperforming systems.With gradually increasing physical infrastructures of irrigation projects, special consideration should be given to the performance of the systems. Irrigation performance assessment is rarely conducted in Ethiopia due to lack of field level data (Seleshi and Mokenen, 2011).

In Ethiopia the largest amount of over supplied water in the semi modern schemes and in traditional schemes was lost in the conveyance and distribution systems (Zeleke. et.al, 2016). For modern schemes water losses in the processes of conveyance was low (26%), while the significant percentage of water (76%) was lost on farm. Public agencies in many developing countries want to support farmer-managed irrigation systems to improve their performance through better management. And, better management is dependent upon suitable methods and measures by which system performance can be assessed relative to themanagement objectives (Oad & Sampath, 1995). Hence, consistent measures of system performance are very important for improving irrigation policy making and management decisions.

The growth potential for small-scale irrigation seems attractive in view of cost effectiveness, well-focused target group and its sustainability through empowerment of the beneficiaries. However, experience has shown that there are still considerable constraints and obstacles thatdelay the introduction of small-scale irrigation. The firstobstacle to irrigation development is the underperformance of existing irrigation schemes and many irrigation projects are operating considerably under their design capacity(Seleshi, 2010).

According to Seleshi Bekele (2010): Research on Irrigation potential of Ethiopia under performance is an issue for all scheme types (small, medium and large) there are multiple reasons for this low performance:

- **Operations/maintenance.** Extensive research shows that non-/underperformance is caused primarily by inadequate operations and maintenance (O&M) of projects, e.g., sedimentation impact, inadequate structural design.
- **Human capacity.** Human capacity is limited across multiple government and private sector actors. This includes a shortage of skilled workers (e.g., engineers, designers) to build and maintain projects and a lack of basic irrigation skills among farmers and development agents to operate and maintain small-scale projects smallholders' limited skills in the operation and maintenance of small-scale projects; and poor contract and performance management for medium- and largescale intervention schemes, among other issues. In addition, scheme performance often deteriorates over time due to wear and tear of irrigation structures and depletion of soil quality, making operations and maintenance especially important.
- **Research/management capabilities.** There is no coordinated research program on agricultural water management, no applied research on national irrigation systems, no link between researchers and farmers, and no manuals on irrigation for local crops. There is also poor management of project contracts and performance – including non-transparent bidding and selection processes, lack of contract management skills, lack of checks and balances – all of which can increase project costs, delivery time, and risk. To address these challenges, the authors recommend several efforts, including prioritizing applied research on irrigated agriculture, enhancing the training of farmers and development agents on agricultural water management through the extension system, and improving contract management for medium and large irrigation schemes.

2.6 Crop-water requirements, irrigation schedules and depths

Despite the fact that the physical determination of crop-water requirements (CWR), irrigation schedules and depths, is complicated and time-consuming, they remain vital to irrigation water management and planning (Abdelhadi. et al., 1999). The introduction of computer models has made it easier and possible to schedule irrigation and supply the exact amounts of water required by crops at every physiological stage in their growth cycle. SapWat (Crosby and Crosby 1999, 2010) and more recently AquaCrop (FAO 2010). The models are based on work done by Doorenbosand Pruitt (1977), Doorenbos and Kassam (1979) and Allen. et al., (1998) and they require information on crop environment (climate and soil) and physiological behavior of the crops to estimate reliable CWR (Smajstrla and Zazueta, 1995). Their estimation is based on statistical methods or physical laws that govern water uptake and use. The main advantage of the models is that they produce very accurate estimates once they have been calibrated for a specific area.

2.7 Performance gaps existing in irrigation management

Performance is evaluated for a variety of reasons: to improve system operations; to assess progress against strategic goals; as an integral part of performance-oriented management, to assess the general health of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance; and to compare the performance of a system with others or with the same system over time. The type of performance measures chosen depends on the purpose of the performance assessment activity (Molden. et al., 1998).

There are four potential kinds of performance gaps that can occur with irrigation systems (Douglas and Juan, 1999).

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

The second kind of performance gap is when a difference arises between how management procedures are supposed to be implemented and how they are actually implemented**.**This includes such problems as 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, supervision or training.

The third kind of performance gap is a difference between management targets and actual achievements. Examples of management targets are the size of area served by irrigation in a given season, cropping intensity, irrigation efficiency, water delivery schedules and water fee collection rates. This can be called a gap in achievement. Such problems are generally addressed either by changing the objectives (especially simplifying them) or increasing the capacity of management to achieve them - such as through increasing the resources available or reforming organizations.

The fourth type of performance problem concerns impacts of management.This is a 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 that the objectives of the organization do notproduce the desired impacts. This is more a problem of policy than management.

2.8 Comparative performance indicators

Comparative indicators are helpful for cross comparison of schemes without looking at internal system specific performance targets. Comparison objectives is to enhance the performance of the schemes through identifying shortcomings and benchmarking best practices (Malano. et al., 2004).Comparative performance evaluation in irrigation schemes is possible through use of comparative indicators. This indicators are based on outputs and inputs from and to an irrigated agricultural system (Molden. et al., 1998). However, they practically supply little or no detail on internal procedures that lead to the output. Unlike internal indicators, which relate performance to internal management targets, external indicators allow comparison between different regions, different infrastructure and management types, and different environments.

Moreover, the trend in performance of a particular scheme can be compared over time. Comparative performance is of major importance to policy makers and managers making long-term and strategic decisions, and researchers searching for relative variations between irrigation systems. Although, in its very concept, external indicators link outputs to inputs, there are indicators for comparative purposes that are not necessarily based on outputs and inputs. Examples are water supply, economic and physical sustainability indicators.

The International Water Management Institute (IWMI) proposed a minimal number of comparative indicators (Molden. et al., 1998): four for agricultural output, two for water supply, one for delivery capacity and two for financial. In this thesis, three groups of applicable comparative performance indicators have been used to compare the performance of the two community managed irrigation schemes in west Harerghe: Homacho sogido and Jawis irrigation scheme. With the many variables that affect performance of irrigated agriculture, which includes infrastructure design, management, climatic conditions, price and availability of inputs, and socioeconomic settings, the task of comparing performance throughout systems is formidable. There are nine comparative performance indicator according to (IWMI, 1998.) and discussed below:

2.8.1 Indicators of Irrigated Agricultural Output

The four basic comparative performance indicators relate output to unit land and water .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. The agricultural output indicator are: output per cropped area, output per unit command, output per unit irrigation water and output per unit water consumed.

2.8.2 Water supply and financial Comparative Indicators

Five additional indicators were identified according to (IWMI, 1998.) for comparative purposes. These are meant to characterize the individual system with respect to water supply and finances. These comparative indicators are Relative water supply, Relative irrigation supply, water delivery ratio and financial indicator (gross return on investments and financial self-sufficiency).

Both RWS and RIS relate supply to demand, and give some indication as the condition of water abundance or scarcity,and how tightly supply and demand are matched.

Financial self-sufficiency tells us what percent of expenditures on Operation and Management is generated locally. If government subsidizes O&M heavily, financial self-sufficiency would be low, whereas if local farmers through their fees pay for most of the O&M expenditures, financial self-sufficiency would be high. Financial self-sufficiency does not tell us the O&M requirement, only the expenditures. A high value of financial self-sufficiency does not automatically indicate a sustainable system as the O&M expenditures might be too low to meet the actual maintenance needs.

2.8.3 Purposes of comparative performance indicators

The comparative indicators 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 indicators have been widely field-tested and slightly amended. The intent of presenting this set of indicators is to allow for cross-system performance. Some of the features of the indicators are the following (Molden. et al., 1998):

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, the set of indicators was 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.

This set of indicators is designed to show gross relationships and trends and should be useful in indicating where more detailed study should take place. For instance, where a project has done extremely well, or where dramatic changes have taken place. 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

3 MATERIAL AND METHOD

3.1. Description of the Study Area

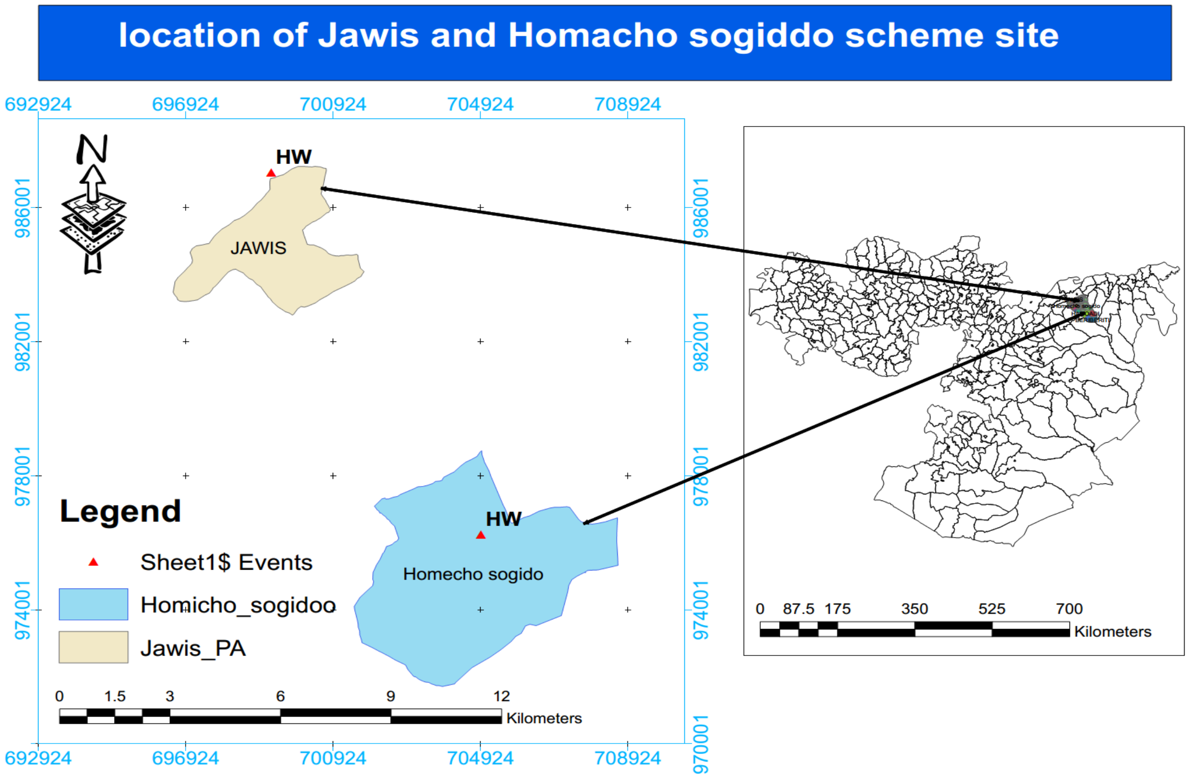

Figure 3.1 Location of Jawis and Homacho scheme with their headwork site.

3.1.1 Homacho sogido

3.1.1.1 Location

Homacho sogidoo small scale irrigation project area is found in Gammachis district of Western Hararghe Administrative zone (Fig 3.3). The project area is situated in peasant association (PA) of Gammachis district namely Homacho sogidoo. The geological location of the head work site lies between 40^0 51' 78.9" E longitude 8^0 49' 55.5" **N** Latitude. Accessibility wise the proposed diversion weir site is found 27km from district town Kuni and 50 km from the .West Harerghe irrigation development authority office. The head work of Homacho irrigation scheme with its components are shown in figure 3.1.

3.1.1.2 Topography & Soil

The topography of the project area is more of mountainous, hilly and rugged, which about 15 % of the area is hilly with slope that ranges from 16 % to 30 %, and the rest 50 % of the area is flat to undulated and gently undulating with slope that ranges from (3-5%) and (5-8%). Topographic nature of the command area is good for efficient use of surface irrigation method. Regarding the command area soil is deep (2 meter) well drained, satisfactory texture and structure (WHIDA, 2009). It is clay to silty clay loam textured which is ideal for irrigation.

The regional geology of the site revealed that the parent material is Limestone formation. The soil the scheme area formed from the weathering action of these rocks has resulted calcite and dolomite soil forming minerals meanwhile, alluvial and colluvial deposition of these transported clay minerals through run-off action coupled with seasonal inundation of the river during rainy season has resulted a clay dominated soil.

3.1.1.3 Climate

The area is belongs to sub-tropical humid agro ecological zone, its altitude 1500-2300 meter above sea level. The area exhibits two main rainy season's one in March to mid-May and the next during July to September. The annual rainfall of the scheme area is 942mm. The maximum and minimum temperature are 29^{o}c and 11^{o}c respectively.

3.1.1.4 Land use

The majority area of Gammachis district, where the project area is located, and exhibit humid agro- climatically condition, the land use of the area is presented in Table (3.1).The land use of the scheme area is cultivated land.

Table3-1 Land use patterns of the Gamechis woreda

	Description	Area (ha)	Percent of total
1	Cultivated land Perennial crop Annual crop	40761 16028 24733	34.46
2	Grazing land	7376	6.23
3	Land for social purposes	8070	6.82
4	Potently arable land	40,400	34.15
5	ForestLand	12617	10.67
6	Bush & Shrubs	9074	7.67
	Total	118,289	100

Source: - woreda Agricultural development office.

3.1.1.5 Farm size and Farming system

The woreda comprises about 118,289 Ha of land &also there is 22703 family head.The land holding per family in the woreda ranges from 0.83 to 1.25 ha.Farmers holding in the command area ranges from 0.125 ha to 0.375 ha and an average land holding per family head to be 0.25 ha.The Homach sogido irrigation scheme was established on the Homacho River using spring which has a base flow of 120 l/s in 2012G.c.

The farming system cereal and shrub crops are dominant and mixed farming where livestock production is undertaken complimentary to crop production in the woreda. The only mono cropping system is adopted in the scheme area. Cropped area farmers practice specific crop rotation system practiced by the farmers and the double cropping is adopted only from the same crop family on the same plots of land. The total command area of the scheme is 125ha having 320 direct beneficiary household heads. The four major user villages of the scheme are Shoro, Sogido, Shebro and Limay villages of Homacho sogido peasant association. In the Homacho irrigation scheme all command area can be irrigable.That means command area and irrigable area are equal according to information obtained from woreda irrigation office and site observation during the measurement of canal flow and there is no residential and grazing land in the command area. The proposed cropping pattern has two cropping seasons, taking place in a year.The major cropping pattern cultivated in the scheme area are Chat, Maize, Sorghum, Mango, Banana and etc. The main source of irrigation water is Perennial River that have a discharge of 120 l /s which is found in PA Homacho sogido. The main irrigation system practiced in the scheme area is a surface irrigation system especially flood irrigation method.

Figure 3.2 Headwork of Homacho sogido irrigation scheme

3.1.2 Jawis scheme

3.1.2.1 Location

Jawis small scale irrigation project area is found in Oda Bultum district of Western Hararghe Administrative zone. The project area is situated in PA'S of Oda Bultum district namely the PA Jawis and Burqa misoma. The geological location of the head work site 69^{o}92'12''E and 98^{o}69'44''N. Accessibility wise the proposed diversion weir site is found 7km from district town Badesa and 40km from the WHIDA Office Chiro. The head work of Jawis irrigation scheme with its components are shown in the figure (3.2).

3.1.2.2 Climate

The area is belongs to sub tropical humid agro ecological zone, its altitude ranges between 1620-2472 meter above sea level. The area exhibits two main rainy season's one in March to mid may and the next during July to September. The annual rainfall of the scheme area is 942.3mm. The average maximum and minimum temperature varies from are 27^{o}c and 11^{o}c respectively.

3.1.2.3 Topography & Soil

The topography of the project area is more of mountainous, hilly and rugged, which about 25% of the area is hilly with slope that ranges from 16% to 30% and the rest 40% of the scheme are flat to undulated and gently undulating with slope that ranges from (3-5%) and (5-8%). Topographic nature of the command area is good for efficient use of surface irrigation. Regarding the command area soil is is deep (2m) well drained, satisfactory texture and structure it is sand to sandy loam textured which ideal for irrigation(WHIDA, 2009).. The dominant soil of the scheme area is sandy soil.

3.1.2.4 Farm size and farming system

The woreda comprises about 130,412 Ha of land &also there is 4,442 house hold head. The land holding per family in the woreda ranges from 0.25 to 1.00 ha. Farmers holding in the command area ranges from 0.125 ha to 0.375 ha and an average land holding per family head to be 0.25 ha. The Jawis irrigation scheme was established on the Jawis River using spring which has a base flow of 70 l /s in 20014G.c. The farming system, irrigation system and land use of Jawis irrigation scheme is similar with that of Homacho irrigation scheme

The total command area of the scheme is 175ha having 420 direct beneficiary household heads. The irrigable area of the scheme is 140ha and the remaining 35ha of land is covered by residential area. The proposed cropping pattern has two cropping seasons, taking place in a year.The major cropping pattern cultivated in the scheme area are Chat, Maize, Sorghum, and etc. The main source of irrigation water is Perennial River that have discharge of 70 l /s which is found in PA Jawis and Mada qacale. The main irrigation system practiced in the scheme area is a surface irrigation system especially flood irrigation method.

Figure 3.3 Headwork of Jawis irrigation scheme

Table3.2 Description of the parameter of the study area

Parameter	Schemes	
	Homacho	Jewis
Year of established	2004E.C	2006E.C
Beneficiaries(HHH)	320	420
Command area(ha)	125	175
Soil type	Clay	Sand
Water sources	river	river
Rainfall(mm)	942	942.3

3.2 Data Collection

In order to achieve the objectives of the study secondary and primary data were used. These data were obtained from the West Harerghe irrigation development authority office, Oda Bulum and Gamachis woreda irrigation offices, nearest meteorological station and FAO-1990 paper. In addition, different project documents, project evaluation and completion reports was refereed.

3.2.1 Primary data collection

The primary data that collectedwere irrigation data such as:total amount of irrigation water diverted per season and actual capacity of main canal (m3/s) werecollected through field observation and direct field measurement.

To calculate the total amount of water diverted to the total irrigated areas within a season, for the two irrigation schemes(Jawis and Homecho)thethree inch parshall flume were installed in the main canal(Figure 3.4).Depth measurement was recorded two times per day afternoon and morning to check the variation of depth measured in the flume due to evaporation, siltation and others factor. Thenthe average of continuous measured depth in the morning and afternoon were used to calculate discharge for two irrigated cropping season in the year for both of the scheme from standard formula developed forthree inches ($3''$) parshall flume (Skogerboe etal, 1966):

$$Q = 0.99(h_a)^{1.55} \qquad (1)$$

Where $h_a = average$ depth of water measured in the flume (ft).

$$Q = Discharge(ft^3/se).$$

Figure 3.4 Field measurement of canal flow

3.2.2 Secondary data collection

Secondary data were collected from the documents kept by the responsible bodies or officials at each irrigation project, Woreda irrigationOffices, and FAO-1990 paper and design document prepared by West Harerghe irrigation development authority offices.

The required secondary data collected for this researchwere climatic data such as:monthly precipitation (mm), mean daily maximum and minimum temperatures, per month (^{o}C), mean monthly wind speed (km/hr), mean monthly relative humidity (%), mean daily hours of sunshine, per month (hours/day) and crop data such as: total command area (ha), cropping pattern of irrigated crops (planting dates, growth length in days),area per crop, per season,(ha), yields, per season (qt/ha), local prices, per season, were collected from nearest meteorological station and Woreda bureau of Irrigation respectively.

3.3 Data analysis method

Analysis of data was carried out by **Cropwat 8** software which used for the analyses ofcrop water demand, irrigation demand and water demand for the overall scheme and **excel worksheet** were used for the analyses of agricultural productivity indicator,physical and water supply indicator.

3.3.1 Comparative performance indicators.

The comparative performance indicators depend on the availability of secondary data. Getting complete data required to calculate all the comparative indicators (the nine indicators)for each small-scale irrigation project was very hard. The sorts of data recorded by irrigation office were limited to the application of all the nine parameters used in the comparative performance indicators developed by IWMI for the same cropping season of the two irrigation projects. Hence, to compare the two-irrigation projects, three sets of comparative indicatorssuch as: water supply indicator, agricultural output indicator and physical indicator were applied with the availableinformation collected and comparative analyses across the two scheme, level of performance for individual scheme are made.

3.3.1.1 Water delivery indicators.

For this study the three water supplyindicators in the minimum set ofcomparative performance indicators were used. The most common water supply indicators are**Annual Relative Water Supply (ARWS)**, **Annual Relative Irrigation supply (ARIS)**, **Water Delivery Capacity (WDC).** They are meant to describe the individual system with respect to water supply (Molden et al, 1998).Relative water supply and relative irrigation supply are used as the basic water supply indicators (Yusuf Kadir, 2004):

$$Annual\ ralative\ water\ supply = \frac{Annual\ water\ supply}{Annual\ Crop\ water\ demand} \qquad (2)$$

$$Annual\ relative\ irrigation\ supply = \frac{Annual\ Irrigation\ supply}{Annual\ Irrigation\ demand} \qquad (3)$$

Where:

Annual water supply= Surface diversions plus rainfall of the year.

Annual Crop demand= Potential crop ET, or the ETunder well-watered conditions in the year.

Annual Irrigation supply = only the surface diversions and net groundwater draft for irrigation in the year but for this study ground water is not considered.

Annual Irrigation demand= the crop ET less effective rainfall in the year.

Both RWS and RIS relate supply to demand, and give some indication as the condition of water adequacy or scarcity, and how adequately supply and demand are matched.

The water delivery capacity (WDC) is given below:

$$Water\ delivery\ capacity(WDC) = \frac{Canal\ capacity\ at\ the\ system\ head}{Peak\ consumptive\ demand} \qquad (4)$$

Where:

Capacity to deliver water at the system head= the present discharge capacity of the canal at the system head.

Peak consumptive demand= the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system.

Water delivery capacity is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptivedemands.

3.3.1.2 Agricultural output indicators

The four basic comparative performance indicators relate output to unit land and water were applied in this study. These “external” indicators provide the basis for comparison of irrigated agriculture performance, according to molden etal, 1998. 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. The outputs of agricultural production in this paper were based on local prices due to similarities of price and irrigation system for both schemes.

Output per unit irrigated cropped area (birr/ha)

It was computed the total value of agricultural production per unit of area under irrigation. The sum of the areas irrigated annually was considered.

$$Output\ per\ unit\ cropped\ area\left(\frac{birr}{ha}\right) = \frac{Annual\ Production}{Annual\ Irrigated\ cropped\ area} \qquad (5)$$

Output per unit command area (birr/ha)

This is the value of agricultural production per unit of nominal or command area which can be irrigated.

$$Output\ per\ unit\ command\ area\left(\frac{birr}{ha}\right) = \frac{Annual\ production}{Command\ area} \qquad (6)$$

Output per unit irrigation water supply (birr/m^3)

This states how well the total annual diverted irrigation water from a source is productive.

$$\text{Output per unit irrigation water supply}(\text{birr}/\text{m}^3) = \frac{\text{Annual production}}{\text{Diverted annual irrigation supply}} (7)$$

Output per unit water consumed (birr/m^3)

$$Output\ per\ unit\ water\ consumed(birr/m^3) = \frac{Annual\ production}{Volume\ of\ water\ consumed\ by\ ET} \qquad (8)$$

Where,

Production is the output of the irrigated area in terms of gross or net value of production measured at local prices, Irrigated cropped area is the sum of the areas under crops, Command area is the nominal or design area to be irrigated, Diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus Volume of water consumed byET is the actual evapotranspiration of crops.

3.3.2 Physicalsustainability indicator

In this study three physical indicators such as: cropping intensity, irrigation ratio and sustainability of irrigated area were used.Physical indicators are related toexpansion or contraction of irrigated land in the command area by different factors. This was calculated using the equation developed by (Vermillion, 2000) as follows:

Cropping intensity- is an indicator used to measure the degree to which irrigated crops are grown in the command area.

$$Cropping\ intensity = \frac{annually\ cropped\ area}{cultivable\ area} \qquad (9)$$

More intensified cropping is indicative of more utilization of the available land resources for crop production. Burton et al. (2000) states that cropping intensities from 100 to 200% are considered good.

$$Irrigation\,ratio = \frac{Irrigated\ area}{irrigable\ area} \qquad (10)$$

Irrigation ratiois the ratio of irrigated area to irrigable command area. It states the degree of utilization of the available nominal or command area for irrigated agriculture at the actual time. For this study the actual irrigated area, command area and initially irrigated area of the two schemes were obtained from woreda irrigation office.

$$Sustainability\ of\ irrigated\ area = \frac{currently\ \ irrigated\ area}{initially\ irrigated\ area} \qquad (11)$$

Where

Currently irrigated area= presently irrigated area of the scheme.In the Homacho irrigation scheme all the command area are under irrigation that means command area and irrigable area are equal and there is no unirrigated area. According to the information gathered from woreda irrigation office and site observation. Initially irrigated area = is the irrigated area of the scheme when it was started to give the service which obtained from the woreda irrigation office of the scheme and the design documents.

3.3.3 Irrigation demand and crop water demand determination

The crop water requirement and Irrigation water requirement of the major crops grown in the both schemes were determined in this study by using CROPWAT 8 model. Where ETO is determined by using Penman-Monteith method calculated from climatic data and effective rainfall is calculated by using USDA soil conservation service.

Crop evapotranspiration (ETc) is the evapotranspiration from disease-free, well fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions (Allen et al., 1998). Crop water requirement may simply be defined as the amount of water required by a crop for its development and maturity. Although crop evapotranspiration can be calculated from climatic data and by integrating directly the crop resistance, albedo and air resistance factors, better the **Penman-Monteith** method is used for the estimation of the standard reference ETcrop and used to determine crop evapotranspiration.

$$ET_C = K_C ET_O \qquad (12)$$

Where Kcis crop coefficient and ETois reference evapotranspiration (mm or mm/day). Reference evapotranspiration (ETo) is the rate of evapotranspiration from a reference crop (green grass) with a height of 8-15 cm, actively growing, completely shading the ground, and no short of water (Allen et al., 1998). The FAO Penman-Monteith method was selected for this study as the method by which the ETo can be unambiguously determined, and the method which provides consistent ETo values in all regions and climates. The modified Penman-Monteith equation reads as:

$$ET_O = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (13)$$

Where:

ET_O = Reference evapotranspiration [mm/day]

R_n = net radiation at the crop surface [MJ/m^{2}day]

G = Soil heat flux density [MJ/m^{2}day]

T = Mean daily air temperature at 2m height [^{o}C]

U_2 = Wind speed at 2m height [m/s]

e_s = Saturation vapour pressure[kpa]

e_a = actual vapour pressure[kpa]

$e_s - e_a$ Saturation vapour pressure deficit[kpa]

g = psychrometric constant [kpa/^{o}C]

Δ = Slope vapour pressure curve [kpa/^{o}C]

FAO CROPWAT model, which were used for determination of crop water requirements, and irrigation water requirement of the irrigated crops and uses the Modified Penman-Monteith equation. ETo is only dependent on climatic parameters. Meteorological data required for calculation of ETоinclude solar radiation, temperature, relative humidity and wind speed. The irrigation requirements of each irrigation schemes were calculated by using the climatic data, cropping pattern, planting dates, and area of each crops.The net crop water requirement and net irrigation water requirement of the two season in the year of study (2010E.C) were calculated by using equation (14).

$$\mathrm{CWR_{crop-1}} \times \left(\frac{\mathrm{Area_{crop-1}}}{\mathrm{Total_{area}}}\right) + \mathrm{CWR_{crop-2}} \times \left(\frac{\mathrm{Area_{crop-2}}}{\mathrm{Total_{area}}}\right) \pm - - - - + \mathrm{CWR_{crop-n}} \times \left(\frac{\mathrm{Area_{crop-n}}}{\mathrm{Total_{area}}}\right) \qquad (14)$$

4. RESULT AND DISCUSSION

4.1. Crop and irrigation requirement

To calculate thewater supply and agricultural indicator for analysis we need to calculate annual crop water demand and annual irrigation water demand of the major crops grown in the schemes. To calculate the crop water requirement and irrigation requirement of the two irrigation schemes: area coverage of the crop, planting and harvesting dates, and total growing of each crop were collected from Woreda irrigation office (appendix A).

In both Jawis and Homacho irrigation scheme no crop rotation was takes place from the first season to the next. That means the same crops are grown in the two irrigated cropping seasons on the same irrigated area.The result of the crop water requirement (CWR) and irrigation requirement (IR) for the Jawis and Homacho sogido irrigation scheme were presented in the Table 4.1 and 4.2 respectively.

Table 4.1 Result of CWR and IR of the Jawis irrigation scheme for two seasons in the year 2010E.C.

	1st season			2nd season		
crop	Area(ha)	CWR(mm/season)	IR(mm/season)	Area(ha)	CWR(mm/season)	IR(mm/season)
Sorghum	12	303.4	30.1	12	303.4	30.1
Maiz	13	307.9	4.1	13	307.9	4.1
Soybean	15	255.9	28.1	15	255.9	28.1
Onion	12	62.7	16.7	12	62.7	16.7
Pepper	3	376.9	63.7	3	376.9	63.7
Tomato	6	150.3	58.9	6	150.3	58.9
Cabbage	4	207.3	60.1	4	207.3	60.1
*Chat**	75	777.1	115.9			
Total	140			65		

Table 4.2 Result of CWR and IR of Homacho irrigation scheme for two cropping season in the year 2010E.C.

1st season				2nd season		
Crop	Area(ha)	CWR(mm/season)	IR(mm/season)	Area(ha)	CWR(mm/season)	IR(mm/season)
Sorghum	8	303.4	30.1	8	303.4	30.1
Maiz	10	348	62.6	10	348	62.6
Soybean	12	274.5	80.3	12	274.5	80.3
Onion	11	62.7	16.7	11	62.7	16.7
Pepper	15	376.9	63.7	15	376.9	63.7
Tomato	15	150.3	58.9	15	150.3	58.9
Cabbage	3	207.3	60.1	3	207.3	60.1
*Sugarcane**	8	900.4	220.6			
*Mango**	5	802.6	125.3			
*Banana**	4	644.4	67.5			
*Chat**	34	777	115.9			
Total	125			74		

**Prennial crop*

The net crop water requirement and net irrigation water requirement were determined for two irrigated cropping seasons of the two schemein the year by using equation (14) and the result is presented in the Table 4.3 and 4.4.

Table4.3 Result of the NCWR and NIWR of the Jawis for the two irrigated seasons in the year of the study (2010E.C).

Season	NCWR(mm/season)	NIR(mm/season)
1st season(Oct-Feb)	524.13	75.1
2nd season(March-July)	232.25	28.02
Total	756.38	103.12

Table 4.4 Result of the NCWR and NIWR of the Homacho for the two irrigated seasons in the year of the study (2010E.C.).

Season	NCWR(mm/season)	NIWR(mm/season)
1st season(Oct-Feb)	469.1	85.1
2nd season(March-July)	248.93	54.51
Total	718.03	139.61

From Table 4.1 observed that the crop water requirement and irrigation requirement of each crop grown in the Jawis scheme in the first and second seasons has been presented. The cropped area of all crops grown in both irrigated seasons were the same since, there is no crop rotation from the first to the second season. The same crop is grown on same area from first season to the second season except perennial crop which exists in both irrigated seasons of the year. By the same means with Jawis the crop water requirement and irrigation water requirement of each crop grown in the Homacho irrigation scheme in both irrigated seasons were presented in Table 4.2. Then the net crop water requirement and Net irrigation water requirement result were calculated by using equation (14) and presented in Table 4.3 and 4.4 for Jawis and Homacho irrigation scheme respectively. From Table 4.3 and 4.4 observed that net crop water requirement of Jawis scheme is greater than the net crop water requirement of Homacho scheme due to more perennial cropping intensity (Chat) in Jawis scheme which is greater than perennial cropping intensity(Chat, Sugar cane, Mango and Banana) of Homacho irrigation scheme. Again from the Table 4.3 and 4.4 observed that net irrigation water requirement of Homacho irrigation scheme is greater than that of Jawis irrigation scheme due to three additional perennial crop grown in the Homacho irrigation scheme.

4.2. Performance measurement

4.2.1 Physical performance indicator

Physical performance indicators are related to the changing of agricultural land in the command area by different reasons and three physical indicators were used for this study such as: irrigation ratio, cropping intensity and sustainability of irrigated land and the data required for this indicator are currently irrigated area, irrigable area and initially irrigated area were collected from woreda irrigation office. But the irrigable area of Jawis scheme was determined by deducting non irrigable area from a total command area. The non-irrigable area was determined by locating the boundary of the area using geographical position system (GPS). These werethen added toArc GIS where the boundaries were plotted and the areas determined. The irrigable area of Homacho sogido irrigation scheme is equal to the command area. Then thethree physical indicators are calculated using the equation 9, 10 and 11 suggested by(vermillion, 2000)

Table 4.5 Summary of the command area and presently irrigated area and initially irrigated area of Jawis and Homacho scheme in 2010E.C.

Scheme	Command area(ha)	irrigable area(ha)	Initially irrigated area(ha)	Cropping intensity(%)	Irrigation ratio(%)	Sustainability of irrigated land(%)
Jawis	175	140	140	146	100	100
Homacho sogido	125	125	105	159	100	119

The cropping intensity, irrigation ratio, and sustainability of Jawis irrigation scheme was calculated by using equation (9), (10) and (11). The result are146%, 100% and 100% respectively. With the same interpretation should be for Homacho sogido irrigation scheme physical indicator were calculated and summarized in Table 4.5.

From Table 4.5 observed that cropping intensity of Jawis and Homacho sogido irrigation scheme are lies between 100 to 200% would imply that both of the irrigation scheme were good according to Burton et al. (2000) states that cropping intensities from 100 to 200% are considered good.

Irrigation ratio has also more or less similar purpose as that of 'cropping intensity' however this considers only the irrigated in one cropping season and not the cropping area on the same plot of land in a year. The irrigation ratio values of Jawis and Homacho schemes shows that 100% of the irrigable land has been irrigated, for both schemes. Also, as observed from Table 4.5 sustainability of irrigated area of Homacho irrigation schemes is greater than unity (1.0) which was 1.19implying that Homacho sogido irrigation scheme is increased,its agricultural landby19%due to the increased discharge of the river according to information obtained from Woreda irrigation officewhich increased due to the best management of the watershed of the scheme area and make the farmer to irrigate additional land. But the sustainability of irrigated land of Jawis irrigation scheme is 1.0 or 100% indicating that the Jawis irrigable area was notexpandingor contracting its agricultural land from the initial one as compared with Homacho scheme due to lower land productivity. According to (zeleke et al, 2012) lower values of sustainability of irrigated areawould implya reduction of agricultural lands which were initially irrigated; and values greater than unity indicate expansion of irrigated area and would imply more sustainable irrigation. From thisHomacho sogido and Jawis irrigation scheme are sustainable in their agricultural land. Generally Homacho irrigation scheme is more sustainable and better utilizations of the available land for irrigated agriculture as compared to Jawis irrigation scheme.

4.2.2. Water supply performances

The three water supply indicator (RWS, RIS and WDR) was used as a parameter to assess the performance level of irrigation schemes. The results are presented in Table 4.9.

In order to change thedepth of crop water requirement to volume the total crop water demand of the scheme from Table 4.3 and 4.4 for the two scheme was multiplied by the total irrigated area, i.e. the result is 1471961.5m^3/year for Jawis irrigation scheme. The total irrigation requirement of the scheme is computed by the same means and the result is 286200.5m^3/year for Jawis irrigation scheme.

The irrigation water management,especially. on water, distribution of the scheme like elsewhere in Harerghe area is handled by the beneficiaries themselves through the appointment of a person locally named as ‘’melka’’ who is responsible for the proper distribution of the water for each user. Though the management of irrigation practice is handled by the beneficiaries themselves through by laws (unwritten agreement) it is reported by farmers that the Peasant Association administration is actively involved in decision making on issues which beyond the control of beneficiary farmers. According to their bylaws, the beneficiaries have agreed on various issues like individual rights and responsibilities, penalty measures upon members who fail to follow their communal agreement and irrigation water usage mechanisms. Hence, every user or beneficiary has the right to use the irrigation water as per the sequence of requests made to the Jawis and his permission. The irrigation hour allocation depends on the size and requirement of their farm.

The measured current discharge capacity of the jawis schemeirrigation canal for the first and second cropping seasons in the year of study was 22l/s and 17l/s respectively. So the farmer was using the water for allowingtime for them one by one based on their request and requirement of their farm which was allowed by the committee of the water user association.Based on this they were using the water 12hr/day and the same water distribution procedure was undertaken for the two irrigation scheme.The only differencein Homacho scheme is the larger discharge of the river (120l/s). And measured currentdischarge capacity of the main canalfor two cropping seasons in the year measured by parshall flumefor Homacho scheme was 28l/s and 25l/s for first and second cropping season respectively.The first season was from Oct to end of Feb and the second season from March to end of July.

Table4.6 Measured values of the canal flow by using standard three inch parshall flume.

scheme	1st cropping season			2nd cropping season			
	Measured depth(ft)	Discharge (ft^3/s)	Q(l/s)	Measured depth(ft)	Discharge (ft^3/s)	Discharge(l/s)	Total discharge(l/s)
Jawis	0.85	0.77	22	0.72	0.6	17	39
Homacho	0.984	0.97	28	0.92	0.87	25	53

The current discharge capacity of the canal is calculated by using the standard three inch parshall flume formula which is described above in equation(1)and annual amount of diverted irrigation water was calculatedas: multiplying the discharge by the total days of the two cropping seasons in the year.

The annual amount of water in depth diverted for irrigation to the command area forthe Jawis scheme was calculated as: annual volume of water diverted divided by total annual irrigated areaand the result is 394.5mm. The total effective rainfall of the area for the two irrigation cropping season for both scheme which calculated by CROPWAT8 was 369.7mm (from the appendix-A) and crop water requirement for the jawis is 756.38 mm.

Table4.7 Result of some parameter forthe two irrigation schemes for the year 2010E.C.

Scheme	Annual diverted water		Command area(ha)	Annual irrigated area(ha)	Annual CWR(mm)	Annual IR(mm)	ARWS	ARIS
	M^3	mm						
Homacho	1099008	552.3	125	199	718.03	139.61	1.3	3.96
Jawis	808704	394.5	175	205	756.38	103.12	1.01	3.83

The water supply indicator ARWS, ARIS and WDR for the Jawis scheme is calculated by using equation 2, 3 and 4 respectively. From this the Annual relative water supply, Annual relative irrigation supply and Water delivery ratio results are 1.01, 3.83 and 1.9 respectively.The peak irrigation requirement of the Homacho and Jawis irrigation scheme is calculated from cropping pattern, planting date of each crop and percent of area coverage of each crop in the scheme by using FAO CROPWAT 8. The result is presented in the Table 4.8.

Table 4.8 Peak IR of the Homacho and Jawis irrigation scheme.

	Scheme	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
R in (l/s/ha	Homacho	0.01	0.01	0	0.01	0.04	0.02	0	0.01	0.02	0
	Jawis	0	0.01	0	0.02	0.05	0.02	0	0.02	0.02	0

From the above Table4.8 the peak irrigation requirement of both irrigation schemes for the two irrigation cropping season in the year of 2010E.C were occurred in the February. The peak irrigation requirement of Jawis irrigation scheme is calculated as i,e peak value times the annual irrigated area and the result is 10.25l/s and 7.96l/s for Jawis and Homacho sogido respectively. The total annual discharge capacity of the canal of Homacho and Jawis is 53l/s and 39l/s respectively. Then the water delivery ratio is calculated by using equation (4) and the result is 1.9 and 3.33 for Jawis and Homacho irrigation scheme respectively.With the same procedure for the Homacho sogido irrigation scheme the water supply indicator of the two irrigation scheme was summarized and presented in Table 4.7.

As we observed from the above Table 4.7 the ARIS is greater than the ARWS for both schemes this indicates that irrigation is the major source of water supply for agriculture in the area.Also observed that the ARIS of the two schemes is greater than 1.0 indicates that excess irrigation water is supplied to the irrigated area. Thewater supply indicators are evaluated as optimal if their values would be equal to one and fewer or larger than one would mean below or over supply of water respectively (Mekonenand Seleshi, 2006).

Higher values ofRIS of Homacho scheme is due to higher accessibility of irrigation water to the farmer as compared to the Jawis irrigation scheme. The ARWS of the two irrigation scheme is approach to one which indicates that the schemes are at optimal levels according to Mekonen and Seleshi stated above.Also ARIS of both schemewas greater than 1.0 imply that oversupply of irrigation water to the scheme which is greater than the crop water requirement.Thiswas caused due to: farmers feel that excess irrigation water application would result in increased yield and divert the water to the schemes.

The water delivery capacity (WDC) is an indicator that tells the canal capability to convey water at a system head to meet the peak consumptive demand, i.e. total capacity of the canal at the head of the scheme to supply the water to the peak irrigation water demand.According to the values of this indicator stated above both Jawis and Homacho sogido irrigation schemes are found to have delivered a large amount ofwater which satisfy the peak consumptive demand of the cropping intensities. Generally the values of RWS and RIS alone in this study imply that water demands of the crops in the schemes are satisfied.

4.2.3. Production performances

To compare the two irrigation scheme four agricultural output indicator was used based on the available data in relation to land productivity and water productivity. The two used land productivity indicator are output per unit cropped area and output per unit command area and the two water productivity indicator are output per unit irrigation water supply and output per unit water consumed. The above four agricultural output indicator are used for comparing thescheme (Molden etal, 1990).

For the year 2009 and 2010E.C total agricultural production and outputs from the products at the local market price (ETbirr) were determined for the two irrigation scheme from the available data and presented in the Table 4.9 and 4.10 respectively.

Table 4.9 Total yield and land coverage of Jawis and Homacho irrigation scheme for year 2009 E.C.

Homacho sogido					Jawis		
Crop	Area (ha)	Avg.yield (qt/ha)	Farm gate unit price(birr/qt)	Total income(birr)	Area(ha)	Avg.yield (qt/ha)	Total income(birr)
Cabbage	18	15	500	135000	26	12	156000
sorghum	20	4	800	64000	20	5	80000
Maiz	32	5	700	112000	38	8	212800
Tomato	16	5	1500	120000	12	9	162000
Soybean	20	4	1200	96000	22	8	211200
Onion	12	10	1200	144000	18	9	194400
Banan	5	6	1200	36000			
Sugarcane	4	250	1000	1000000			
Mango	3	5	1800	27000			
Khat	34	11	1500	561000	72	15	1620000
Total	164	315	11400	2295000	208	62	2636400

Table 4.10 Total yield and cropping pattern and land coverage of Jawis and Homacho irrigation scheme for the year 2010 E.C.

Homacho sogido					Jawis		
Crop	Annual irriigted area(ha)	Avg.yield (qt/ha)	Farm gate unit price(birr/qt)	Total income(birr)	Annual irrigated area(ha)	Avg.yield (qt/ha)	Total income(birr)
Cabbage	6	15	750	67500	8	18	108000
Tomato	30	6	1800	324000	12	7	151200
Sorghum	16	8	850	108800	24	10	204000
Soybean	24	6	1700	244800	26	11	486200
Onion	22	9	1500	297000	24	16	576000
Maiz	20	10	750	150000	30	11	247500
Pepper	30	3	3500	315000	6	5	105000
Banana	4	12	1500	72000			
Sugarcane	8	250	1100	2200000			
Mango	5	12	1800	108000			
Khat	34	16	1500	816000	75	14	1575000
Total	199	347	14650	4703100	205	92	3452900

As observed in the Table 4.9 crop production for the year 2009 of the Homacho sogido and a Jawis irrigation scheme were 3682qt and 2242qt respectively, which was obtained from the sum of $(col - 2 \times col - 3)$. The annual cropped area of Homacho sogido was 164ha with annual gross income of 2295000birr and the cropped area ofthe Jawis irrigation scheme was 208ha with annual gross income of 2636400birr in the year 2009E.c. The command area of the Jawis was 175ha and that of Homacho was 105ha. The cropped area of the two irrigation scheme was greater than the command area because all of the crops were cultivated twice per year except perennial crop. For the year 2010 the total annual crop production of Jawis was 2548qt with gross income of 3452900birr.

The command area of the Homacho Sogido irrigation scheme was developed from 105ha to 125ha in 2010E.c. Because of increment of dischargeof the river according to the information gathered from woreda irrigation office.

Table 4.11 Command area, cropping area, irrigation water and yield of the Jawis and Homacho irrigation scheme.

Parameter	**Year**	**Homacho**	**Jawis**
Command area(ha)	2009	105	175
Annual cropped area(ha)		164	208
Water consumed(m^3)			
Irrigation supplied(m^3)			
Production(birr)		2295000	2480400
Command area(ha)	2010	125	175
Annual cropped area(ha)		199	205
Water consumed(m^3)		1428820	1550579
Irrigation supplied(m^3)		1099008	808704
Production(birr)		4703100	3452900

The two land productivity, comparative indicators were determined for Jawis irrigation scheme by using equation 5 and 6. The result of OPUIA and OPUCA are 11925birr/ha and 14173.7birr/ha respectively. But the water productivity for the year 2009 was not calculated because of non-availability of flow measurement data. The four agricultural productivity was determined for Jawis irrigation schemein theyear 2010. The result of OPUIA and OPUCAare 16843.4birr/ha and 19730.86birr/ha respectively.

Then to determine Water productivity indicator the depth of irrigation water diverted from the source were measured withthree inch standard Parshall flumes.The measurement of the depth of water in the flume was taking place two times per day and the average depth was adopted.Then, based on these depths thedischarge of the cropping seasons in the year of analysis were calculated by using equation (1) stated above. The continuous measurement for first cropping season (Oct-Feb) and the second cropping season (March- July) was undertaken. The consumed water is the actual crop evapotranspiration determined based on the parameter such as: cropping pattern, climate and rainfall data and soil of the command area. Then CWR and IR were determined by using FAO CROPWAT model version 8. Thenbased on these value obtainedfrom the model water productivity indicators were calculated for Jawis irrigation scheme by using equation 7 and 8. And the result of OPUIWS and OPUWC are4.27birr/m^3 and 2.23birr/m^3.

With the same procedures, the values of agricultural indicator for Homacho sogido and Jawis were determinedand summarized in the Table 4.12 for year 2009 and 2010E.C.

Table 4.12 Summary of the calculated agricultural indicator for the Jawis and Homacho scheme in the year 2009 and 2010E.C.

Indicator	Year	Homacho	Jawis
Output per unit irrigated area (Birr/ha)	2009 E.C	13993.9	11495
Output per unit command area (Birr/ha)		21857	18260.6
Output per unit water consumed(Birr/m^3)			
Output per unit water supplied(Birr/m^3)			
Output per unit irrigated area (Birr/ha)	2010E.C	24304.5	16843.4
Output per unit command area (Birr/ha)		38692.8	19730.86
Output per unit water consumed(Birr/m^3)		3.29	2.23
Output per unit water supplied(Birr/m^3)		4.28	4.24

From the Table 4.12 the output per unit cropped area and output per unit command area of Homacho sogido was greater than that of Jawis in the year 2009E.c.Again from Table 4.12 in the year of 2010 also observed that output per unit irrigated area and output per unit command area of Homacho was greater than that of Jawis. This was due to larger cropping pattern in Homacho sogido irrigation scheme.In addition to similar crops grown in both scheme Homacho contain three additional high value perennial crops such as: Banana, Mango and Sugarcane, which did not grow in the Jawis scheme andcomparatively more accessibility of irrigation water in Homacho. Also, as observed from the Table 4.12 the land productivity of both schemes were developed from year 2009 to 2010 this was due to the increment of market of the production and production in qt/ha but comparatively the Homacho scheme was better land productivity in both 2009 and 2010E.C.In caseof water productivity indicator-output per unit irrigation water supply of the Homacho and that of Jawisare almost equal as observed from Table4.12.Which implying that bothof the scheme is good in effective utilization oftheir irrigation water.But comparatively Homacho irrigation scheme is better in effective utilization of water. And from the Table 4.12 the result of output per unit water consumed of Homacho irrigation scheme is greater than that of Jawis. This shows that the crops grown in Homacho scheme yield more compared to Jawis.The higher values of OPUIW and OPUWC of the Homacho irrigation scheme is due to more accessibility of water to farmer which make the farmer to grow more cropping pattern in the scheme. The results of performance with respect both the land and water productivity imply that Homacho scheme performs better and benchmark to the scheme in the zone.

4.3. Evaluation of performance gaps

From the three comparative indicator used in this study the gap of the Homacho and Jawis irrigation scheme can be observed from the figure 4.1, 4.2 and 4.3 of the physical, water delivery and production indictor respectively.

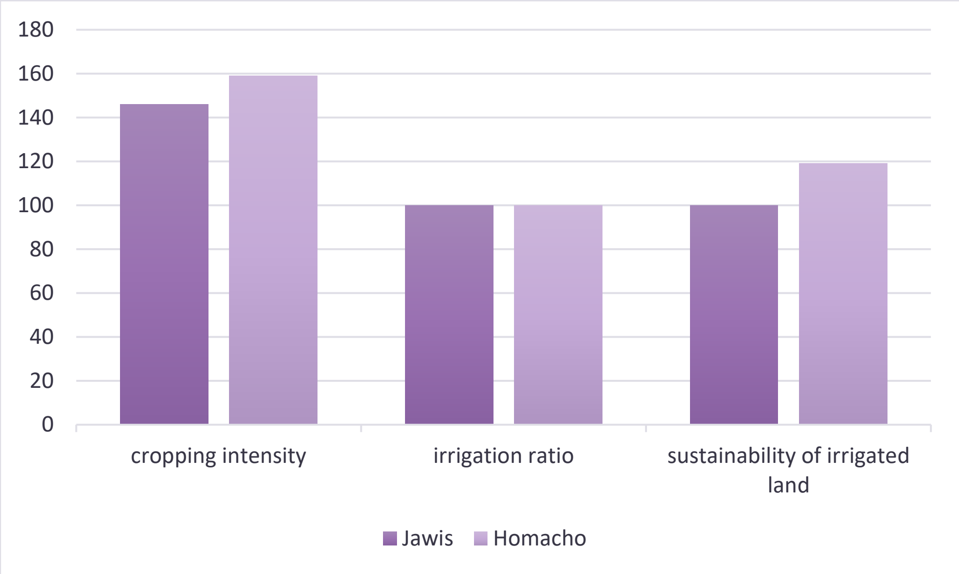

Figure 4.1 Pysical indicator of the Homacho and Jawis irrigation scheme

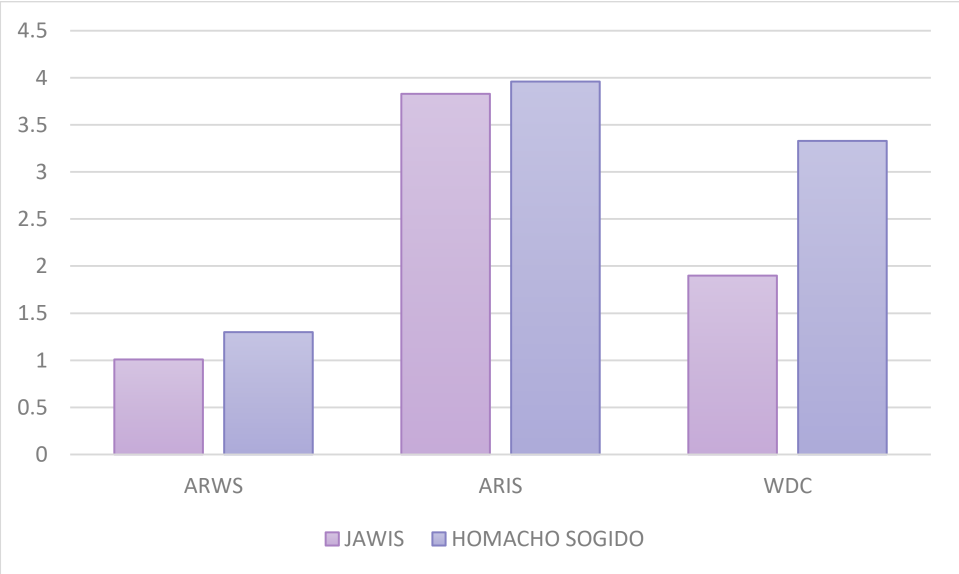

Figure 4.2 Water delivery indicator of the Homacho and Jawis irrigation scheme.

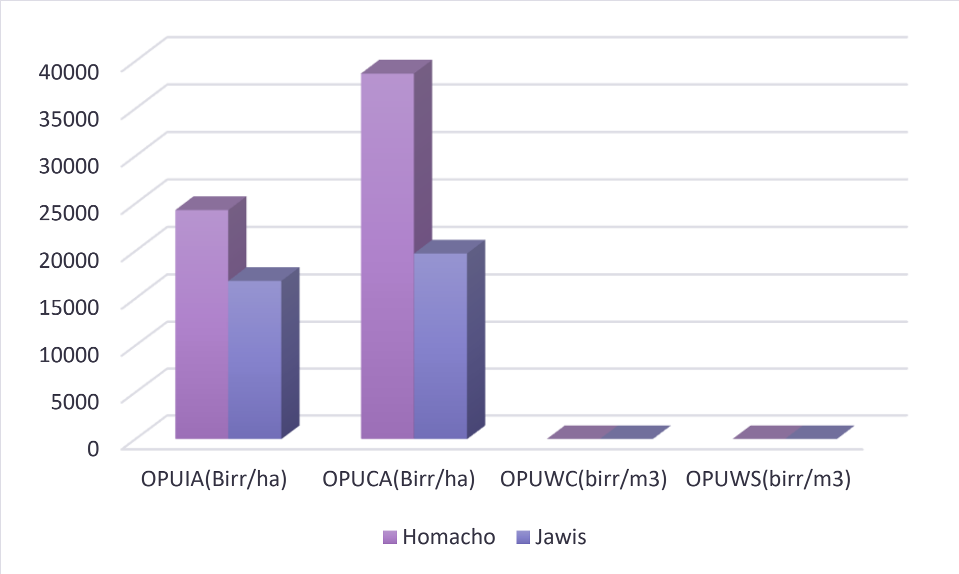

Figure4.3 Land and water productivity indicator of Homacho and Jawis indicator.

From the above figure 4.1 observed that the values of the three physical indictor of the Homacho andJawis irrigation schemes are effectively utilizes the available land. Butcomparatively higher values of cropping intensity and sustainability of irrigated land of Homacho irrigation scheme indicates that Homacho scheme is more sustainable. From the figure 4.2 observed that water delivery indictor, RWS and WDC of the two schemes are approach to one implying that there is no constraining cropping intensity in both schemes according to molden etal, 1998. But water delivery indicator especially RIS of Homacho and Jawis scheme is high which is greater than one indicates that excess application of irrigation water to the irrigated land by farmer. This gap on relative irrigation water supply are due to lack of sound irrigation scheduling and lack of knowledge on water demand of different crop types grown in the schemes. As observed from the figure 4.3 production performance indicatorin there was a considerable gap on land productivity indicator (OPUCA and OPUIA) between Homacho and Jawis irrigation scheme due to the variation in high value cropping pattern grown in Homacho scheme.

As discussed in the literature there are four types of performance gaps existing in irrigation management according to Dougles and Juan (1999) out of this the third and fourthperformance gaps were observed in this study based on the arises in the scheme.The third gaps occurred when a difference arises between management targets and actual achievements which includes water delivery schedules and the fourth gaps is management impacts- this is a difference between what people think should be the ultimate effects of irrigation and what actually results. The farmers of the two schemes feels that excess irrigation water application would result in increased yield. And lack of proper irrigation and water delivery schedules are the reason for the above two gap.

4.4. Improvement options

Excess application of irrigation water problem can be improved by preparing the water measurement device for the water user of the scheme in order to balance supply and demand of the water based on the crop water demand. And give the training for the farmers on the crop water requirement based on the major crop pattern in the scheme and on the procedure of using the instrument for measuring the amount of water which diverted into the field. Then RIS values is minimized by regulating the irrigation release from diversion structures to effectively use the water supply by adjusting the gate.

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this study, the comparative performance assessment of two small scale irrigation scheme was carried out using comparative performance indicator. This indicator is useful to compare different irrigation scheme to evaluate the degree of utilization of the available natural resources such as: land, water and component of the scheme. The indicator used are: water supply indicator, agricultural output indicator and physical indicator.From the results of performance indicator with respect to physical indicator are the irrigation ratio of the Jawis and Homacho irrigation schemes are 100% implies that they are effectively utilizes the available land for irrigation.Thesustainability of irrigated landof the Homacho and Jawis schemes are 119% and 100% respectively. Higher values of the sustainability of irrigated land of Homacho scheme implies that the agricultural land of the Homacho irrigation scheme hasbeen expand its irrigated land by 19% from the initially irrigated area. This is due to more accessibility of irrigation water and the increased discharge of the river that make the farmer to irrigate additional land. Then from the discussed physical indicator it can be concluded that both irrigation schemes are effectively utilized their available land for irrigation. But comparatively Homacho irrigation scheme is more sustainable.

The ARIS is greater than the ARWS for both Jawis and Homacho irrigation scheme this indicates that irrigation water is the major source of water supply in addition to effective rainfall for agriculture in the area.The ARIS of the two schemes are greater than 1.0 indicates that excess irrigation water is supplied to the irrigated area which greater than the crop water demand.The output per unit cropped area and output per unit command area of Homacho was greater than that of Jawis in the year 2009 and 2010. This was due to the larger cropping pattern and more accessibility of irrigation water to the farmers in the Homacho irrigation scheme as compared to the Jawis irrigation scheme. The OPUIA and OPUCA of both schemes was increased from 2009 to 2010 due to increasing of the marketprice of the product and production in quintal per hectare. The output per unit irrigation water supply and output per water consumed ofthe Homacho irrigation scheme is greater than that of Jawis irrigation scheme. Higher values of OPUIWS and OPUWC of the Homacho irrigation scheme indicates that Homacho irrigation scheme is better in effective utilization of the available land and water resources for irrigation.

Excessive annual irrigation water was supplied in both scheme due to lack of knowledge on water diversion by farmer to irrigated area. This can be improved by training the farmer to control the diversion of water based on crop water demand. In general, in 2009 and 2010 the Homacho sogido irrigation scheme was more productive due to additional high value perennial crops grown in the scheme in addition to major crop grown in both schemes. Therefore Homacho irrigation scheme could be benchmarked in the zone for both water and land productivity.

5.2 Recommendation

- Assigning DA and Office assistant for the water user association have more importance to the improvement of irrigation projects, especially on water diversion and overall irrigation water management.
- During the irrigation time of the scheme close monitoring should be practiced by an experienced worker from the woreda irrigation office rather than completely left the operation for the farmer in order to balance crop water requirement and the amount of water supplied to the irrigated area.
- Additional research should be done on the overall performance of the small scale irrigation scheme in the West Harerghe zone in order to assess internal and external performance of the scheme.

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7 APPENDICES

Appendix-A Climatic, Rainfall, crop data and Parshall flume

Parshall Flume

The Parshall measuring flume is a water measuring device that can be used to measure water flowing in an open channel. It is proposed primarily for use in irrigation, and consists of a converging inlet section, a throat section with straight parallel sides, and a diverging outlet section. The two most desirable features of the flume are that it operates very satisfactorily with a loss of head much less than required for a weir, and under normal operating conditions, the discharge can be determined with an accuracy of 2 to 5 percent (Skogerboe etal, 1966).

Discharge through the flume is called "free flow" when the water elevation downstream is not high enough to affect flow conditions upstream. However, when the water elevation downstream is not high enough to affect flow conditions upstream. However, when the water elevation downstream is high enough to affect conditions upstream, submerged flow occurs.

Free flow is the condition under which the rate of discharge depends only upon the depth of flow (Ha) (Fig. A-1) in the converging section. For a Parshall flume, the free-flow discharge relationship remains valid for a relatively high degree of submergence, thus allowing a wide range of downstream flow conditions. For free flow conditions, the submergence should not exceed the limits as given in Table A-1. The submergence, which is often expressed as a percentage, is the ratio of the downstream head (Hb) to the upstream head, Ha, (Hb/Ha) (Fig.A-1).

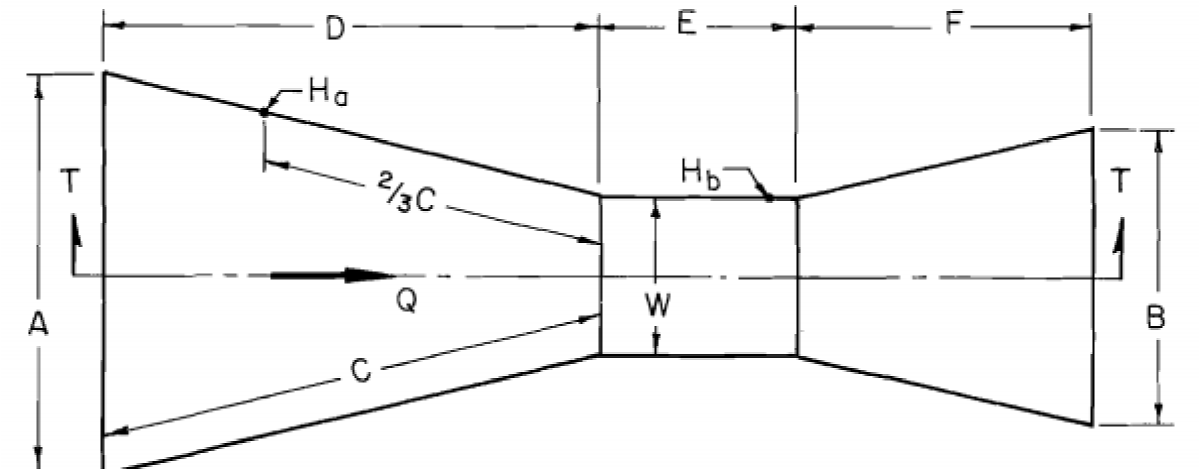

Figure A-1 Plan and sectional view of parshall measuring flumes (Skogerboe etal, 1966).

Table A-1 Transition submergences in parshall flumes (Skogerboe etal, 1966).

Flume Size	Transition Submergence	Flume Size	Transition Submergence	Flume Size	Transition Submergence
3"	56%	18"	64%	4'	70%
6"	56%	24"	66%	5'	72%
9"	60%	30"	67%	6'	74%
12"	62%	3'	68%	7'	76%
				8'	78%

Table A-2 Potential crop grown in the Jawis scheme

S.no	Crops	Annual irrigated area		Planting date	Harvesting date	Total growing (day)
		ha	%			
1	Sorghum	24	11.71	Oct	Feb	150
2	Maiz	30	12.7	Oct	Jan	140
3	Soybean	26	14.63	Oct	Jan	110
4	Onion	24	11.71	Oct	Jan	120
5	pepper	6	2.9	Oct	Feb	150
6	Tomato	12	5.85	Oct	Jan	120
7	Cabbage	8	3.9	Oct	Jan	120
8	Khat	75	36.6	Perennial	-	-
	Total	205	100			

Table A-3Potential crop grown in the Homacho sogido irrigation scheme.

S.no	Crops	Annual irrigated area		Planting date	Harvest date	Total growing(day)
		ha	%			
1	sorghum	16	8	Oct	Feb	150
2	Maiz	20	10.1	Oct	Jan	140
3	Soybean	24	12.1	Oct	Jan	110
4	Onion	22	11.1	Oct	Jan	120
5	pepper	30	15.1	Oct	Feb	160
6	Tomato	30	15.1	Oct	Jan	120
7	Cabbage	6	3	Oct	Jan	120
8	Sugar cane	8	4			Perennial
9	Mango	5	2.5			-
10	Banana	4	2			-
11	Chat	34	17.1			-
	Total	199	100			

Table A-4 Effective and total precipitation

Station: Gelemso

Eff. rain method: USDA Soil Conservation Service formula:
Peff = Pmon * (125 - 0.2 * Pmon) / 125 for Pmon <= 250 mm
Peff = 125 + 0.1 * Pmon for Pmon > 250 mm

	Rain mm	Eff rain mm
January	8.8	8.7
February	11.3	11.1
March	59.5	53.8
April	130.4	103.2
May	127.6	101.5
June	72.8	64.3
July	131.6	103.9
August	165.0	121.4
September	137.7	107.4
October	56.4	51.3
November	26.5	25.4
December	15.1	14.7
Total	942.7	766.8

Table-A5 Climatic parameter and ETO

Country: ETHIOPIA Station: Gelemso
Altitude: 1739 m. Latitude: 40.52 °N Longitude: 8.81 °E

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	11.8	26.2	51	2	8.5	10.4	0.64
February	12.2	27.8	50	2	8.3	13.0	1.41
March	13.8	28.5	47	2	7.8	15.9	2.34
April	14.8	27.5	61	1	7.0	17.9	3.18
May	14.9	27.7	68	1	7.1	19.8	3.76
June	15.0	27.8	67	1	7.1	20.4	3.95
July	15.1	26.8	69	1	6.0	18.5	3.58
August	14.9	26.2	72	1	5.8	16.8	3.15
September	14.3	26.4	74	1	5.7	14.3	2.50
October	14.8	26.5	61	1	6.7	12.3	1.72
November	14.4	26.5	62	1	7.6	10.3	1.03
December	11.4	25.4	51	2	8.7	9.7	0.43
Average	14.0	26.9	61	1	7.2	14.9	2.31

Table-A6 Water requirement of Banana

ETo station: Gelemso
Rain station: Gelemso

Crop: BANANA 1st year
Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.50	0.63	6.3	10.9	0.0
Nov	2	Init	0.50	0.52	5.2	7.8	0.0
Nov	3	Init	0.50	0.42	4.2	6.8	0.0
Dec	1	Init	0.50	0.31	3.1	6.0	0.0
Dec	2	Init	0.50	0.21	2.1	4.7	0.0
Dec	3	Init	0.50	0.25	2.7	4.1	0.0
Jan	1	Init	0.50	0.28	2.8	3.3	0.0
Jan	2	Init	0.50	0.32	3.2	2.5	0.7
Jan	3	Deve	0.50	0.45	4.9	2.9	2.0
Feb	1	Deve	0.52	0.60	6.0	2.2	3.9
Feb	2	Deve	0.55	0.78	7.8	1.8	6.0
Feb	3	Deve	0.58	1.00	8.0	7.2	0.8
Mar	1	Deve	0.61	1.24	12.4	13.0	0.0
Mar	2	Deve	0.64	1.50	15.0	17.6	0.0
Mar	3	Deve	0.67	1.76	19.4	23.2	0.0
Apr	1	Deve	0.70	2.04	20.4	30.5	0.0
Apr	2	Deve	0.73	2.33	23.3	36.8	0.0
Apr	3	Deve	0.76	2.58	25.8	35.8	0.0
May	1	Deve	0.79	2.83	28.3	35.1	0.0
May	2	Deve	0.82	3.10	31.0	35.5	0.0
May	3	Deve	0.86	3.27	36.0	30.8	5.2
Jun	1	Deve	0.89	3.45	34.5	23.2	11.3
Jun	2	Deve	0.92	3.63	36.3	17.8	18.4
Jun	3	Deve	0.95	3.63	36.3	23.4	12.9
Jul	1	Deve	0.98	3.63	36.3	30.9	5.4
Jul	2	Mid	1.00	3.59	35.9	35.6	0.3
Jul	3	Mid	1.00	3.45	38.0	37.2	0.7
Aug	1	Mid	1.00	3.31	33.1	39.5	0.0
Aug	2	Mid	1.00	3.16	31.6	41.9	0.0
Aug	3	Late	1.00	2.94	32.3	39.9	0.0
Sep	1	Late	0.97	2.64	26.4	38.7	0.0
Sep	2	Late	0.94	2.35	23.5	37.7	0.0
Sep	3	Late	0.92	2.05	12.3	18.5	0.0
					644.4	703.1	67.5

Table-A7 Water requirement of Cabbage

ETo station: Gelemso
Rain station: Gelemso

Crop: CABBAGE Crucifers
Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	0.88	8.8	10.9	0.0
Nov	2	Init	0.70	0.72	7.2	7.8	0.0
Nov	3	Init	0.70	0.58	5.8	6.8	0.0
Dec	1	Init	0.70	0.44	4.4	6.0	0.0
Dec	2	Deve	0.73	0.31	3.1	4.7	0.0
Dec	3	Deve	0.78	0.39	4.3	4.1	0.2
Jan	1	Deve	0.84	0.48	4.8	3.3	1.5
Jan	2	Deve	0.89	0.57	5.7	2.5	3.2
Jan	3	Deve	0.95	0.85	9.4	2.9	6.4
Feb	1	Mid	1.00	1.16	11.6	2.2	9.4
Feb	2	Mid	1.02	1.43	14.3	1.8	12.5
Feb	3	Mid	1.02	1.75	14.0	7.2	6.8
Mar	1	Mid	1.02	2.07	20.7	13.0	7.7
Mar	2	Mid	1.02	2.39	23.9	17.6	6.2
Mar	3	Late	1.02	2.67	29.4	23.2	6.2
Apr	1	Late	0.97	2.82	28.2	30.5	0.0
Apr	2	Late	0.92	2.92	11.7	14.7	0.0
					207.3	159.3	60.1

Table-A 8 Water requirements of Maize

ETo station: Gelemso
Rain station: Gelemso

Crop: MAIZE (Grain)
Planting date: 01/06

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Jun	1	Init	0.30	1.16	11.6	23.2	0.0
Jun	2	Init	0.30	1.18	11.8	17.8	0.0
Jun	3	Deve	0.43	1.64	16.4	23.4	0.0
Jul	1	Deve	0.66	2.45	24.5	30.9	0.0
Jul	2	Deve	0.89	3.20	32.0	35.6	0.0
Jul	3	Mid	1.09	3.76	41.3	37.2	4.1
Aug	1	Mid	1.11	3.67	36.7	39.5	0.0
Aug	2	Mid	1.11	3.51	35.1	41.9	0.0
Aug	3	Mid	1.11	3.27	36.0	39.9	0.0
Sep	1	Late	1.04	2.83	28.3	38.7	0.0
Sep	2	Late	0.80	1.99	19.9	37.7	0.0
Sep	3	Late	0.54	1.21	12.1	30.9	0.0
Oct	1	Late	0.38	0.74	2.2	6.7	0.0
					307.9	403.5	4.1

Table A-9 Water requirement of Chat

ETo station: Gelemso
Rain station: Gelemso

Crop: Khat
Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	1.00	1.26	12.6	10.9	1.7
Nov	2	Init	1.00	1.03	10.3	7.8	2.6
Nov	3	Init	1.00	0.83	8.3	6.8	1.5
Dec	1	Init	1.00	0.63	6.3	6.0	0.3
Dec	2	Init	1.00	0.43	4.3	4.7	0.0
Dec	3	Init	1.00	0.50	5.5	4.1	1.4
Jan	1	Init	1.00	0.57	5.7	3.3	2.4
Jan	2	Init	1.00	0.64	6.4	2.5	3.9
Jan	3	Deve	1.00	0.90	9.9	2.9	6.9
Feb	1	Deve	0.99	1.14	11.4	2.2	9.3
Feb	2	Deve	0.98	1.38	13.8	1.8	12.0
Feb	3	Deve	0.97	1.67	13.4	7.2	6.2
Mar	1	Deve	0.96	1.96	19.6	13.0	6.6
Mar	2	Deve	0.95	2.23	22.3	17.6	4.7
Mar	3	Deve	0.94	2.47	27.2	23.2	4.0
Apr	1	Deve	0.93	2.70	27.0	30.5	0.0
Apr	2	Deve	0.92	2.93	29.3	36.8	0.0
Apr	3	Mid	0.91	3.07	30.7	35.8	0.0
May	1	Mid	0.91	3.23	32.3	35.1	0.0
May	2	Mid	0.91	3.40	34.0	35.5	0.0
May	3	Mid	0.91	3.46	38.1	30.8	7.3
Jun	1	Mid	0.91	3.52	35.2	23.2	12.0
Jun	2	Mid	0.91	3.58	35.8	17.8	17.9
Jun	3	Mid	0.91	3.47	34.7	23.4	11.2
Jul	1	Mid	0.91	3.36	33.6	30.9	2.7
Jul	2	Mid	0.91	3.25	32.5	35.6	0.0
Jul	3	Late	0.91	3.12	34.3	37.2	0.0
Aug	1	Late	0.91	2.99	29.9	39.5	0.0
Aug	2	Late	0.90	2.85	28.5	41.9	0.0
Aug	3	Late	0.90	2.65	29.2	39.9	0.0
Sep	1	Late	0.90	2.45	24.5	38.7	0.0
Sep	2	Late	0.90	2.25	22.5	37.7	0.0
Sep	3	Late	0.90	2.02	20.2	30.9	0.0
Oct	1	Late	0.90	1.78	17.8	22.4	0.0
Oct	2	Late	0.90	1.54	15.4	15.7	0.0
Oct	3	Late	0.90	1.34	14.7	13.3	1.4
					777.1	766.8	115.9

Table A-10 Water requirements of Mango

ETo station: Gelemso
Rain station: Gelemso

Crop: MANGO
Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.90	1.13	11.3	10.9	0.5
Nov	2	Init	0.90	0.93	9.3	7.8	1.5
Nov	3	Init	0.90	0.75	7.5	6.8	0.7
Dec	1	Init	0.90	0.57	5.7	6.0	0.0
Dec	2	Init	0.90	0.39	3.9	4.7	0.0
Dec	3	Init	0.90	0.45	4.9	4.1	0.8
Jan	1	Init	0.90	0.51	5.1	3.3	1.8
Jan	2	Init	0.90	0.58	5.8	2.5	3.2
Jan	3	Deve	0.90	0.81	8.9	2.9	5.9
Feb	1	Deve	0.91	1.05	10.5	2.2	8.3
Feb	2	Deve	0.92	1.29	12.9	1.8	11.1
Feb	3	Deve	0.93	1.60	12.8	7.2	5.6
Mar	1	Deve	0.94	1.90	19.0	13.0	6.0
Mar	2	Deve	0.95	2.22	22.2	17.6	4.6
Mar	3	Deve	0.96	2.52	27.7	23.2	4.4
Apr	1	Deve	0.97	2.82	28.2	30.5	0.0
Apr	2	Deve	0.98	3.12	31.2	36.8	0.0
Apr	3	Mid	0.99	3.34	33.4	35.8	0.0
May	1	Mid	0.99	3.54	35.4	35.1	0.3
May	2	Mid	0.99	3.73	37.3	35.5	1.8
May	3	Mid	0.99	3.80	41.8	30.8	10.9
Jun	1	Mid	0.99	3.86	38.6	23.2	15.4
Jun	2	Mid	0.99	3.92	39.2	17.8	21.4
Jun	3	Mid	0.99	3.80	38.0	23.4	14.6
Jul	1	Mid	0.99	3.68	36.8	30.9	5.9
Jul	2	Mid	0.99	3.56	35.6	35.6	0.0
Jul	3	Late	0.99	3.42	37.6	37.2	0.3
Aug	1	Late	0.98	3.22	32.2	39.5	0.0
Aug	2	Late	0.95	3.01	30.1	41.9	0.0
Aug	3	Late	0.93	2.73	30.0	39.9	0.0
Sep	1	Late	0.91	2.46	24.6	38.7	0.0
Sep	2	Late	0.88	2.21	22.1	37.7	0.0
Sep	3	Late	0.86	1.93	19.3	30.9	0.0
Oct	1	Late	0.84	1.66	16.6	22.4	0.0
Oct	2	Late	0.82	1.41	14.1	15.7	0.0
Oct	3	Late	0.80	1.18	13.0	13.3	0.0
					802.6	766.8	125.3

Table A-11 Water requirements of Sorghum

ETo station: Gelemso
Rain station: Gelemso

Crop: SORGHUM (Grain)
Planting date: 01/05

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
May	1	Init	0.30	1.07	10.7	35.1	0.0
May	2	Init	0.30	1.13	11.3	35.5	0.0
May	3	Deve	0.41	1.55	17.1	30.8	0.0
Jun	1	Deve	0.59	2.31	23.1	23.2	0.0
Jun	2	Deve	0.77	3.05	30.5	17.8	12.7
Jun	3	Mid	0.91	3.50	35.0	23.4	11.5
Jul	1	Mid	0.92	3.42	34.2	30.9	3.3
Jul	2	Mid	0.92	3.31	33.1	35.6	0.0
Jul	3	Mid	0.92	3.18	35.0	37.2	0.0
Aug	1	Late	0.88	2.91	29.1	39.5	0.0
Aug	2	Late	0.74	2.32	23.2	41.9	0.0
Aug	3	Late	0.58	1.69	18.6	39.9	0.0
Sep	1	Late	0.48	1.30	2.6	7.7	2.6
					303.4	398.7	30.1

Table A-12 Water requirements of Onion

ETo station: Gelemso
Rain station: Gelemso

Crop: Onion
Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	0.88	8.8	10.9	0.0
Nov	2	Init	0.70	0.72	7.2	7.8	0.0
Nov	3	Deve	0.76	0.63	6.3	6.8	0.0
Dec	1	Deve	0.86	0.54	5.4	6.0	0.0
Dec	2	Deve	0.97	0.42	4.2	4.7	0.0
Dec	3	Mid	1.02	0.51	5.6	4.1	1.5
Jan	1	Mid	1.02	0.58	5.8	3.3	2.5
Jan	2	Late	1.02	0.65	6.5	2.5	4.0
Jan	3	Late	0.97	0.87	9.6	2.9	6.7
Feb	1	Late	0.93	1.07	3.2	0.6	2.1
					62.7	49.7	16.7

Table A-13 Water requirements of Sugarcane

ETo station: Gelemso
Rain station: Gelemso

Crop: Sugarcane (Ratoon)
Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.40	0.50	5.0	10.9	0.0
Nov	2	Init	0.40	0.41	4.1	7.8	0.0
Nov	3	Init	0.40	0.33	3.3	6.8	0.0
Dec	1	Deve	0.47	0.30	3.0	6.0	0.0
Dec	2	Deve	0.60	0.26	2.6	4.7	0.0
Dec	3	Deve	0.74	0.37	4.0	4.1	0.0
Jan	1	Deve	0.87	0.50	5.0	3.3	1.6
Jan	2	Deve	1.00	0.64	6.4	2.5	3.9
Jan	3	Mid	1.13	1.01	11.2	2.9	8.2
Feb	1	Mid	1.17	1.35	13.5	2.2	11.4
Feb	2	Mid	1.17	1.65	16.5	1.8	14.7
Feb	3	Mid	1.17	2.02	16.2	7.2	9.0
Mar	1	Mid	1.17	2.39	23.9	13.0	10.9
Mar	2	Mid	1.17	2.75	27.5	17.6	9.9
Mar	3	Mid	1.17	3.08	33.9	23.2	10.7
Apr	1	Mid	1.17	3.41	34.1	30.5	3.6
Apr	2	Mid	1.17	3.74	37.4	36.8	0.6
Apr	3	Mid	1.17	3.96	39.6	35.8	3.8
May	1	Mid	1.17	4.19	41.9	35.1	6.7
May	2	Mid	1.17	4.41	44.1	35.5	8.6
May	3	Mid	1.17	4.48	49.3	30.8	18.5
Jun	1	Mid	1.17	4.56	45.6	23.2	22.4
Jun	2	Mid	1.17	4.63	46.3	17.8	28.5
Jun	3	Mid	1.17	4.49	44.9	23.4	21.5
Jul	1	Mid	1.17	4.35	43.5	30.9	12.6
Jul	2	Mid	1.17	4.21	42.1	35.6	6.5
Jul	3	Late	1.17	4.03	44.3	37.2	7.1
Aug	1	Late	1.13	3.72	37.2	39.5	0.0
Aug	2	Late	1.07	3.39	33.9	41.9	0.0
Aug	3	Late	1.02	2.98	32.8	39.9	0.0
Sep	1	Late	0.96	2.60	26.0	38.7	0.0
Sep	2	Late	0.90	2.26	22.6	37.7	0.0
Sep	3	Late	0.85	1.90	19.0	30.9	0.0
Oct	1	Late	0.80	1.57	15.7	22.4	0.0
Oct	2	Late	0.74	1.27	12.7	15.7	0.0
Oct	3	Late	0.68	1.02	11.2	13.3	0.0
					900.4	766.8	220.6

Table A-14 Water requirements of Tomato

ETo station: Gelenso
Rain station: Gelenso

Crop: Tomato
Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.60	0.76	7.6	10.9	0.0
Nov	2	Init	0.60	0.62	6.2	7.8	0.0
Nov	3	Init	0.60	0.50	5.0	6.8	0.0
Dec	1	Deve	0.67	0.42	4.2	6.0	0.0
Dec	2	Deve	0.80	0.34	3.4	4.7	0.0
Dec	3	Deve	0.93	0.47	5.1	4.1	1.0
Jan	1	Mid	1.07	0.61	6.1	3.3	2.8
Jan	2	Mid	1.12	0.71	7.1	2.5	4.6
Jan	3	Mid	1.12	1.00	11.0	2.9	8.1
Feb	1	Mid	1.12	1.28	12.8	2.2	10.7
Feb	2	Mid	1.12	1.57	15.7	1.8	13.9
Feb	3	Late	1.09	1.88	15.0	7.2	7.9
Mar	1	Late	0.99	2.02	20.2	13.0	7.2
Mar	2	Late	0.87	2.05	20.5	17.6	2.9
Mar	3	Late	0.79	2.06	10.3	10.6	0.0
					150.3	101.4	58.9

Table A-15 Water requirements of Soybean

ETo station: Gelemso
Rain station: Gelemso

Crop: Soybean
Planting date: 01/06

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Jun	1	Init	0.40	1.55	15.5	23.2	0.0
Jun	2	Deve	0.47	1.85	18.5	17.8	0.7
Jun	3	Deve	0.88	3.38	33.8	23.4	10.4
Jul	1	Mid	1.09	4.04	40.4	30.9	9.5
Jul	2	Mid	1.09	3.91	39.1	35.6	3.5
Jul	3	Mid	1.09	3.75	41.3	37.2	4.0
Aug	1	Late	1.09	3.58	35.8	39.5	0.0
Aug	2	Late	0.81	2.55	25.5	41.9	0.0
Aug	3	Late	0.50	1.48	5.9	14.5	0.0
					255.9	264.2	28.1