JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDROLOGY AND HYDRAULIC ENGINEERING CHAIR

MASTERS OF SCIENCE PROGRAM IN HYDROLOGY AND HYDRAULIC ENGINEERING

PERFORMANCE EVALUATION OF JIDA IRRIGATION PROJECT IN JIMMA GENETI DISTRICT, HORO GUDURU WOLLEGA ZONE, OROMIYA, ETHIOPIA

BY: HABTAMU ASEFA

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF JIMMA UNIVERSITY INSTITUTE OF TECNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR DEGREE OF MASTERS OF SCIENCE IN HYDRAULIC ENGINEERING

March , 2021

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DECLARATION

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in Jimma University or any other university and that all sources of materials used for the thesis have been fully acknowledged.

Name Signature

Habtamu Asefa ____________ Date __________

Approval of the advisors

Advisor: Dr:- Eng Tamene Adugna Signature ____________ Date _________

Co advisor: Mr. Abebe Chala Signature______________ Date _________

This is to certify that the thesis prepared by Habtamu Asefa, entitled: **"performance evaluation of Jida Irrigation project In Jimma Geneti District, Horo Guduru Wollega Zone, Oromia"** and submitted in partial fulfillment of the requirements for the degree of Master of Science in Hydraulic Engineering compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee:

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ABSTRACT

Evaluating the performance of irrigation systems is to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency. This study was carried out at Jida Irrigation project with the objectives of characterization of the project, analysis and performance evaluation of Jidda irrigation project. This study primarily focuses on the technical characterizing the scheme, as well as technical and economic performance evaluation of JIP, assessing the determinants of intensity of irrigation water use. The results are expected to be useful for policy makers and different organizations that are involved in the promotion of irrigation development in the region and at national level, contribute baseline information for further studies on economic aspects of irrigation water use, determine the willingness of the users to maintain, keep and manage the scheme element determinants of irrigation water used decisions and would add to the existing stock of knowledge on irrigation that may important for researchers.While conducting this study primary and Secondary data was made to visualize the study area. The scheme performance evaluation was made by comparing the functionality of the structures with the design and by measuring the canals discharge capacity using performance indicators such as conveyance, application, storage and over all irrigation project efficiencies along with the water productivity in terms of water use efficiency respectively. Average conveyance, application and storage efficiencies were obtained as 75.68%, 56% and 54.3% respectively. Productivity of the cropping system can be improved by minimizing water losses. Therefore, the major recommendations are forwarded for sustainable resource utilization. Preparation of extra drainage system is necessary for the scheme to avoid accumulation of excess water in the lower spots that leads to deep percolation loss.

Key words: *Characterization, Efficiency, Water Productivity, Irrigation, Drainage system, Performance*

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TABLE OF CONTENTS

Conents **Page**

LIST OF TABLE

Table **Page**

LIST OF FIGURE

Figures **Page**

ACRONOMYS

CSA	Central Statics Agency
CWP	Crop Water Productivity
DA's	Developmental Agents
DU	Distribution Uniformity
Er	Water Storage Efficiency
ETo	Reference Evapo transpiration
Es	Irrigation Efficiency
Etc	Estimated Water used by Crops
Ec	Conveyance Efficiency
Ea	Application Efficiency
EWP	Economic water productivity
Ep	Over all scheme Efficiency
es	Saturation Vapor pressure
ea	Actual vapor pressure
FAO	Food and Agricultural Organization
GPS	Geographical positioningsystem
GDP	Growth Development project
GIS	Geographical information system
IWR	Irrigation Water requirement
IWMI	International water management Institute
JIP	Jidda Irrigation project
LSI	Large scale Irrigation
MOARD	Ministry of Agriculture and rural development
MOWR	Ministry of water resource
MSI	Medium Scale Irrigation
NGO's	Non governmental organization
SSI	Small scale Irrigation
OIDA	Oromia Irrigation development Agency
OWWCE	Oromia Water Work construction Enterprise
Pe	Effective Rainfall
Ww	Weghit of wet soil
Wd	Weghit of dry soil
W	Width of canal
WUA	Water user Association
Yi	Yield of Irrigation crop

1. INTRODUCTION

1.1. Back Ground

Like other developing countries, Ethiopia's economy depends mainly on agriculture. In order to increase agricultural production, the development of irrigation and agricultural water management holds significant potential. According to (FAO, 2010), Ethiopia has about 72 million ha of potentially suitable land for agriculture, of which about 15 million ha has been cultivated. The potentially irrigable land of Ethiopia is estimated to be about 5.3 million ha (Zeleke, 2015). In addition, the country owns 12 river basins that provide an estimated runoff 125 billion cubic meter, much of this run-off could be used for irrigation and other purposes (Selesh, 2010). However, in Ethiopia only 10% of the estimated potential irrigable land is actually irrigated and 2% of cultivated lands are irrigated (Gebremedhin and Asfaw, 2015). Similarly, irrigated agriculture comprises only 3% of the total national food production Bacha *et al.*, (2011). These indicated, although the county has abundant arable land and water resources, its agricultural system does not yet fully benefit from the technologies of water management and irrigation.

Irrespective of country's endowment with potentially huge irrigable land and water resources, the area of land under irrigation so far is not much more than about 3% showing that water resources have made little contribution towards the development of irrigated agricultural sector up to now (Water Sect Policy, 2001).

It can also easily be realized that besides to the underdeveloped irrigation, the accelerated population growth and the disparity of rainfall distribution make a big challenge for production of sufficient food and attaining food security.(Pawlak, 2010).

To overcome such problems, the Oromia Regional Government also has identified resources, potential land, command area which are presently under different phases of study and implementation. Jida Irrigation Project (JIP) is one of the small-scale irrigation projects, which is planned by the regional government of Oromia in the Horo Guduru Wollega Zone In Jimma Geneti district.

Therefore, the Oromia Irrigation Development Authority /OIDA/ decided to intervene in the situation, through the Jida Irrigation Project In 2007E.C. Irrigation development, which can contribute for food security, employment and agro-industry, but the challenge in attaining such sound irrigation, is not easy. The need to increase agricultural productivity and attain food security is now here more pressing than in Ethiopia, which has become a typical case of recurring famines and food insecurity, and is a major recipient of foreign food aid (Ersado, 2005).

One of the options to increase agricultural productivity is in irrigation development. JIP currently is supplying irrigation water for 30ha out of 60ha planned. The project has started to irrigate before Five years and it passed nearly eight to ten irrigation seasons at different irrigation based on the completion of farm irrigation water supplying structures and land distribution.

The primary objective of this research was JIP, in order to evaluate and appraise the existing overall situation of water conveyance system, management practices and to quantify the hydraulic performance with internal (process) indictors. In addition, maintenance performance of the scheme was also assessed. Lastly, after evaluating and ranking the performance of the system based up on the hydraulic performance indicators and maintenance based parameters remedial measures was documented in order to support decision maker for effective operation, maintenance and management of the system.

1.2. Statement of the Problems

Irrigated agriculture has made a major contribution to the food production and food security throughout the world. Without irrigation, much of the impressive growth in agricultural productivity over the last 50 years could not have been achieved (FAO, 2017). Nevertheless, it is widely accepted that the overall performance of irrigation and drainage investments has too often been fallen short of the expectations of planners, governments and financing institutions (FAO, 1996).

The major focuses of the irrigation development initiatives in the Oromia region were on the constructions or engineering aspects. However, issues such as, water use rights and allocation, operation and maintenance, and establishment and strengthening of evaluation of the performance is also should be the most essential part of project management (MOWR, 2002)

Jida Irrigation Project also the problem of timely completion, planning construction and efficiently performing problem. There is a need for research and capacity building to understand the complex issues of water use and water management, to deal with land management issues to enhance food security, to reduce poverty and speedup national economic development.

In view of JIP problems, knowing the efficiencies and the effectiveness of water use at farmer's level to alleviate the current challenges caused by inefficient operation of irrigation system and poor management of irrigation water that would help to improve the performance of the irrigation system in terms of efficiencies is of paramount importance. Therefore, it is necessary to assess the gains and information that can improve the performance of such irrigation investment in order to achieve incremental production, to create a sense of ownership and consequent commitment to the project performance evaluation and characterization.

1.3 Objectives of the Study

1.3.1 General Objective of the Study

The General objective of the study is to analysis the technical efficiencies and evaluate the performance of Jida Irrigation project using performance indicators.

1.3.2 Specific Objectives of the Study

i. To Investigate the situation of existing Irrigation practice at Jida irrigation project.
ii. To evaluate the technical Performance Evaluation of Jida Irrigation project.
iii. To examine the Level of water productivity in terms Economic performance of the irrigation project.

1.4 Research Questions

1. Is the situation of existing irrigation practice in the project appropriate?
2. What is the status of technical performance evaluation of Jida Irrigation project?

3. What is the level of water productivity of JIP in terms of economic performance?

1.5 Significance of the study

Irrigation technology is one means by which agricultural production can be increased to meet the growing demand for food. This implies that irrigation is one of the ranges of technologies available to increase agricultural production and maximize household income to improve rural livelihood. Thus, this study primarily focuses on the technical characterizing the scheme, as well as technical and economic performance evaluation of JIP, assessing the determinants of intensity of irrigation water use. The results are expected to be useful for policy makers and different organizations that are involved in the promotion of irrigation development in the region and at national level, contribute baseline information for further studies on economic aspects of irrigation water use, determine the willingness of the users to maintain, keep and manage the scheme element determinants of irrigation water used decisions and would add to the existing stock of knowledge on irrigation that may important for researchers.

1.6 Scope of the Study

The study is aimed at identifying the problems in construction, maintenance, performance and timely completion of such projects and irrigation scheme as well as assessing the intensity of irrigation water use. This study is limited to the Oromia National Regional State, Horo Guduru Wollega zone. This is mainly because of limited availability of resources to undertake the study at a wider scale. For the same reason, the sample size is limited to few respondents.

Irrigation is much more complex, dynamic and also requires multidisciplinary approach which uses different criteria based on interest of group, disciplinary, professions and values. The thesis was conducted from Sept, 2020, to , January 2021.

2. LITERATURE REVIEW

2.1 Irrigation Water Control and Management

According to (Hemant Singh, 2015) "Water management" is defined as the planned development, distribution, and use of irrigation water in accordance with predetermined objectives and with respect to both quantity and quality of the water resources. It is the specific control of all human intervention on surface and subterranean water. Every planning activity that has something to do with water can be looked upon as water management in the broadest sense of the term. According to (U.S Bureau of Reclamation 2005) "Irrigation Water Management" means management of irrigation water on the farm. There is no way that the cultivated area without a water management system can contribute significantly to the required increase in food production (Schultz and De Wrachien, 2002). The on-farm irrigation water need to be measured to determine the potential efficiency of the systems as designed and the actual efficiency that is obtained with present management (Marie-Helene Berner *et al*., 2010).

2.2. Importance of Irrigation in Agriculture

In Ethiopia, there is uneven distribution of rain fall spetially and temporally. This, uneven spatial and temporal distribution of rainfall in the country adds to the problems of agricultural production. Irrigation development is key to the sustainable and reliable agricultural development, and thus for the overall economic development of the country. In order to ensure food security at the household level for Ethiopia's fast growing population, small, medium and large scale irrigation infrastructure needs to be developed. Such development could also generate externally marketable surplus that would earn the much needed foreign exchange and provide required raw material to the local industries(G.Medihn G.Meskel Haile, 2015)

The principal objective of the irrigation development strategy is to exploit the agricultural production potential of the country, to achieve food self sufficiency at the national level, including export earnings, and to satisfy the raw material demand of local industries, but without degrade the fertility and productivity of country's land

and water resources base. More specific objectives of the strategy are to: expand irrigated agriculture, improve irrigation water-use efficiency and thus the agricultural production efficiency, develop irrigation system that are technically and financially sustainable.(Ethiopian Water sector Strategy, 2001)

Towards this end, develop complementary infrastructures and share development costs with other sectors, and involve relevant institutions in the planning and development of schemes. Also, enhance the adoption of improved agricultural practices based on detailed agronomic and agricultural studies of crops, soils, farming practices, efficient irrigation methodology that will contribute to improved irrigation systems management. Of all economic sectors, agriculture is the sector where water scarcity has the greatest relevance. Currently, agriculture accounts for 70 percent of global fresh water withdrawals, and more than 9 percent of its consumptive use. Under the joint pressure of population growth and changes in dietary habits, food consumption is increasing in most regions of the world. It is expected that by 2050 an additional billion tons of cereals and 200 million tons of meat will need to be produced annually to satisfy growing food demand (FAO, 2012).

The global water crisis has drawn worldwide attention to the urgency of achieving a more efficient use of water resources, particularly in agriculture, to increase crop production and achieve world food security. Considering that a major share of the world`s water resource issued in agriculture and that food requirements are increasing while global water resources are limiting irrigated agriculture and therefore, the role of efficient irrigation systems and techniques have recently assumed greater importance in increasing food production (Dabour, 2002). FAO pointed out that, over the past 30 years, the world’s total agricultural production doubled, while the expansion of cultivated land was only about 15 percent and all of this growth was occurred in land equipped for irrigation (FAO, 2012).

FAO recently reviewed the current status and role of irrigation in 93 developing countries, and assessed the likely situation of irrigation in 2015 and 2030. The main results of the study, in terms of agricultural production, land under irrigation and agricultural water use are presented. The study shows that fears of a looming crunch between population growth and land availability are unwarranted. According to the same source in the recent past, world demand for agricultural products has slowed, driven mostly by a decreasing rate of population growth and the fairly high levels of food consumption reached in many countries. Future demand growth will slow further. If, at the global level, the production potential exists to cope with increasing demand, developing countries will be more dependent on agricultural imports, and production in poor areas must increase if food security is to improve. The same applies to land and water resources.

The study also forecasts, in the future, 80 percent of increased crop production in developing countries will come from intensification: higher yields, increased multiple cropping and shorter fallow periods. Cropping intensities and yields are systematically higher in irrigated than in rain fed areas. The remaining 20% will come from expansion of agricultural land, mainly in countries showing important potential. To meet future food demands and growing competition for clean water, a more effective use of water in both irrigated and rain fed agriculture will be essential. Options to increase water-use efficiency include harvesting rainfall, reducing irrigation water losses, and adopting cultural practices that increase production per unit of water K.Descheemaeker *et al*., (2013)

2.3. Overview of Irrigation Development in Ethiopia

Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops in Awash Valley for the first time. Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal irrigation schemes in the late 1950s in the upper and lower Awash Valley. In the 1960s, irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley Sileshi *et al*., (2010).

2.4 Current Status of Irrigation in Ethiopia

The current estimates of irrigation schemes of the country cover about 640,000 ha. However, there is some uncertainty about the exact number and location of some schemes, particularly small-scale irrigation and rainwater harvesting (RWH). These irrigation schemes vary widely in size and structure, from micro irrigation (RWH), to river diversion, pumping, and small or large dams, etc. These schemes can be subdivided into: Large-scale irrigation,(LSI) covering more than 3,000 hectares, which is typically commercially or publicly sponsored(Seleshi *et al.*, 2010).

SSI (small scale irrigation) schemes are the responsibility of the MOARD and regions, while MSI and LSI are the responsibility of the MOWR. Seleshi *et al.* 2010 pointed out that it is relatively easy to identify and map LSI and MSI, the information related to SSI is not readily available and data about many RWHs are extremely difficult to capture due to poor information management and availability of data.

The current development has been focusing on the development of small scale irrigation. To address the problem of food security, and to meet the demands of food and fiber requirement, the country has prepared a five year growth and transformation plan to develop additional 1.16 M ha of land, which is an increase of around 280 percent of the currently irrigated land. SSI and RWH will account for about two-thirds of this expansion, as they require lower capital and technical investments, labor is available, they are able to reach fragmented communities and households, and they are possible on small plain areas (Seleshi *et al.*, 2010).

2.5. Irrigation Status In Oromia

Oromia is the largest state in terms of both population and land area in Ethiopia. It covers a total geographical area of about 355,000 square km. The region is characterized by immense geographical diversity consisting of high and hugged contoured mountains dissected by the great East African Rift Valley. Oromia has an estimated total population of 28,067,000 of which 24,165,687 (86.1 percent) of the population are estimated to be rural inhabitants, while 3,901,313 (3.9 percent) are urban (CSA, 2008).

In Oromia, river diversion schemes have been built or rehabilitated. Non-governmental organizations and communities are also undertaking water resource development activities such as water harvesting. Besides development of new schemes, some traditional systems are also being rehabilitated.

One of the major problems related to the sustainable use of irrigation schemes that have been developed by government in many developing countries including Africa is lack of financial resources for covering operational and maintenance costs.

2.6. Technical Characterization and Performance Evaluation of Irrigation Projects

The major focus of the irrigation development initiatives in the region were on the constructions or engineering aspects. However, issues such as beneficiaries' selection, water use rights and allocation, operation and maintenance, and establishment and strengthening of water users associations are important for sustainable and effective irrigation development.

2.6.1 Characterization

2.6.1.1. Soil Characterization

On the design document, integrated water shade management plans; both engineering measures and bio measures were recommended. However, on the field visit, no water shade management work was implemented whether to protect the main canal or to protect flood coming in the canal with canal silting materials.

Based on soil depth, slope and salinity characteristics a total of soil mapping units (SMU) were identified, excluding the rocky and hilly units. High soil pH, salinity, soda city and coarser soil texture are the prominent characteristics of the soils restricting the suitability of the soils for various crops (OIDA design doc., 2000).
The crop suitability evaluation indicated that onion, maize, sorghum, cabbage and pepper could be cultivated by irrigation. The soils in the western part of the study area have better potential for irrigation development than the soils in the eastern part.

2.6.2. Performance Evaluation

2.6.2.1. Importance of Performance Evaluation

Many scholars emphasized the importance of performance evaluation for an irrigation system. Much of the work to date in irrigation performance assessment has been focused on both external and internal processes of irrigation systems. These process indicators relate performance to management targets such as timing, duration, and flow rate of water, area irrigated and cropping patterns. (C.Santos et al., 2010) stated that effective irrigation management requires reliable performance assessment. Good farm irrigation management assures correct frequency of irrigations, correct application depth, uniform irrigation, minimum runoff, and minimum deep percolation except for that required for salt management, minimum erosion, and optimal return on irrigation investment.

Performance evaluation is basically to ensure all activities proceed smoothly as planned towards achieving those objectives and that system managers are alerted easily to potential threats to crop and production system performances and react in time to avoid or overcome the situation when it occurs. Specially, some of the major roles of performance assessment and evaluation are to ensure that the cropping intensity targets met, for accurate supply demand matching, water savings and to alert potential crisis event.(Tesfaye M, 2017)

Evaluation of farm irrigation systems specially plays a fundamental role in improving surface irrigation, a system which is usually considered inefficient in terms of water use. Evaluation of the system provide information used to advise irrigators on how to improve their system design and/or operation, as well as information on improving design, and developing real time irrigation management decisions. According to FAO (1989) the principal objective of evaluating surface irrigation systems is to identify management practices and system configurations that can be feasibly and effectively implemented to improve the irrigation efficiency. An evaluation may show that higher efficiencies are possible by reducing the duration of the inflow to an interval required to apply the depth that would refill the root zone soil moisture deficit. The evaluation may also show opportunities for improving performance through changes in the field size and topography.

Evaluations are useful in a number of analyses and operations, particularly those that are essential to improve management and control. Evaluation data can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year. The surface irrigation system is a complex and dynamic hydrologic system and, thus, the evaluation processes are important to optimize the use of water resources in this system (AF Marshal, 2020).

2.6.2.2. Purpose of Irrigation Performance Evaluation

The performance of an irrigation system is represented by its measured levels of achievement in terms of one or several parameters that are chosen as indicators of the system"s goals (Style and Marino, 2002). The cause of the poor irrigation performance has been blamed on technical, financial, managerial, social, and/or institutional causes. As Prasad and Jayakumar (2003) indicated performance assessment practices are very much essential because of their central role in effective management. Dawit et al. (1997) defined performance as a measure of “how close an irrigation event (scenario) is to the reference irrigation”. Performance assessment in irrigation and drainage can be defined as the systematic observation, documentation and interpretation of activities related to irrigated agriculture with the objective of continuous improvement. Performance assessment is an activity that supports the planning and implementation process. The ultimate purpose of performance assessment is to achieve an efficient and effective use of resources by providing relevant feedback to the project management at all levels (Molden *et al*., 2004).

Schultz and De Wrachien (2002) described that the aim of performance assessment is to select a small number of powerful, easily observable indicators that allow reliable conclusions to be drawn. The performance assessment should be a regular, short-duration process for investigating suspected critical shortfalls in performance. According to (Bos, 2000) the wider objectives of performance assessment is to upgrade management capabilities in both public and private sector irrigation and drainage projects with a view to improving the efficiency with which available resources are used. As such, the assessment should become part of the routine management procedures of the irrigation institution.

Small and Svendsen (1992) identified four different interrelated purposes of performance assessment: operational, accountability, intervention and sustainability. Operational performance assessment relates to the day-to-day, season-to-season monitoring and evaluation of system or scheme performance. Accountability performance assessment is carried out to assess the performance of those responsible for managing a system or scheme. Intervention assessment is carried out to study the performance of the scheme or system and, generally, to look for ways to enhance that performance. Performance assessment associated with sustainability looks at the longer-term resource use and scheme or system impacts.

(R.Sakthivadivel *et al*., 2001) described that the responsibilities of irrigation managers in irrigation performance assessment encompass (1) evaluating the existing situation of irrigation performance in their systems, (2) identifying constraints to proper performance if the performance is not satisfactory, and (3) implementing management interventions to improve the performance. At all levels, performance must be assessed using a combination of targets and associated set of standards that describe the acceptable range of values around that target (Bos *et al*.1994).

2.6.2.3. Performance Assessment

Performance assessment in irrigation and drainage can be defined as the systematic observation, documentation and interpretation of activities related to irrigated agriculture with the objective of continuous improvement. Performance assessment is an activity that supports the planning and implementation process. The ultimate purpose of performance assessment is to achieve an efficient and effective use of resources by providing relevant feedback to the project management at all levels Molden *et al*., (2004).

According to (Bos *et al*., 2000), the wider objectives of performance assessment are: to upgrade management capabilities in both public and private sector irrigation and drainage projects with a view to improving the efficiency with which available resources are used. As such, the assessment should become part of the routine management procedures of the irrigation institution. Mall and Svendsen (1992) identify four different interrelated purposes of performance assessment: operational, accountability, intervention and sustainability.

Molden *et al*., (1998) stated that performance is assessed for a variety of reasons: to improve system operations, to assess progress against strategic goals, as an integral part of performanceoriented 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. It is recommended not to start with too many indicators since each of them require data to be collected. Based on the objectives, however, one or more indicator should be selected from each of the three major disciplines: Water delivery and discharge; Environment and sustainability and Socio-economics.

It is insufficient to simply look at the inputs and outputs of an irrigation project. It is absolutely necessary to understand the internal mechanisms of irrigation projects, and to provide selective enhancement of those internal mechanisms, if irrigation project performance is to be improved Burt and Styles, (1999). At all levels, performance must be assessed using a combination of targets and associated set of standards that describe the acceptable range of values around that target Bos *et al*., (1994).

2.6.2.3.1. Framework of Performance Assessment

Regarding the different approaches of soliciting evaluation data, it can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year. The other means of collecting the evaluation data is through conducting assessment research. The types of performance measures (indicators) to be chosen depend on the purpose of the performance assessment activity Molden *et al*., (1998). With these indicators the amount of deviation between the actual values against the intended are evaluated.

2.6.2.4. Irrigation Efficiency

According to Magayane M *et al*., (2004) irrigation water use efficiency is the ratio between the volume used by plants throughout the evapo transpiration process and the volume that reaches the irrigation plots and indicates how efficiently the available water supply is being used, based on different methods of evaluation. The design of the irrigation scheme, the degree of land preparation, and the skill and care of the irrigators are the principal factors influencing irrigation efficiency. Efficiency in the use of water for irrigation consists of various components and takes into account losses during storage, conveyance and application to irrigation plots. Identifying the various components and knowing what improvements can be made is essential to making the most effective use of this but scarce resource.

According to Keller *et al*., (1996), the classical overall irrigation system efficiency (Es) is defined as the volume of water used beneficially (net crop evapo transpiration) divided by the volume of water diverted. Effective efficiency (EE) is defined as the ratio of net crop evapo transpiration divided by the net volume of water delivered to a field. The volume of water that becomes unusable, surface runoff or deep percolation is subtracted from the total volume delivered when calculating the denominator ratio.

Irrigation efficiency has a tremendous impact on agricultural water demands. Understanding how irrigation efficiency fits into estimation of water requirements is essential.(Zadalis *et al*.,1997) considered the effective rainfall in the definition of efficiency. The mean irrigation efficiency for each system is defined by the ratio of the net volume actually used by the crops and the volume released at the head of the main canal.

The most common way to express the efficiency of irrigation systems is to subdivide it into conveyance and application efficiencies. Once the conveyance and field application efficiency have been determined, the scheme irrigation efficiency (ES) can be calculated, using the following formula (FAO, 1989).

According to (FAO, 1989) a scheme irrigation efficiency of 50–60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20–30% is considered to be poor. It should be kept in mind that the values mentioned above are only indicative values.

The performance of farm irrigation is determined by the efficiency with which water is diverted, conveyed, and applied; and by the adequacy and uniformity of application in each field on the farm. Among the factors used to judge the performance of an irrigation system or its management, the most common ones are efficiency and uniformity. These parameters have been subdivided and defined in a multitude of ways as well as named in various manners.

Common performance indicators defined by Kloezen and Garces-Restrepo (1998), based on literature include:

- conveyance efficiency, distribution efficiency, field efficiency, application efficiency and project efficiencies;
- reliability and dependability of water distribution;
- equity or spatial uniformity of water distribution; and
- adequacy and timeliness of irrigation delivery

2.6.2.5. Irrigation Performance Indicators

Performance indicators measure the value of a particular item such as yield or canal discharge and have to include a measure of quality as well as of quantity, and be accompanied by appropriate standards or permissible tolerances (Rust and Snellen, 1993). In connection with main system performance, the authors concluded that the services provided by the system and the appropriate performance standards are greatly influenced by the design of that system. The improvement of irrigation practice requires knowledge of crop water requirement and yield responses to water, the constraints that are specific to each irrigation method and irrigation equipment, the limitation to water supply system, and the financial and economic implication of irrigation practice.

Improvement of irrigation method requires the considerations of the factors influencing the hydraulic process, the water infiltration and uniformity of water application to the entire field (Hlavek, 1992). The consideration of the different factors renders irrigation management a complex decision-making and field practice process (Periera and Luis, 1999)

Performance evaluation exercises are meaningful if related with certain management objectives that are defined for certain given situation. Some key indices or terms are developed that are used to describe the achievement of these objectives, followed by the identification of variables that are controllable and measurable and can be regulated to achieve the established indicators. The indices are used to evaluate the farm irrigation system that could be categorized into delivery subsystem (the system extending from head-works to field canals), and water use subsystem (part of the system extending from field canals to water application system). The indices should be subjected to management control so that they can be manipulated to improve system performance (Walker and Skogerobe, 1987).

Efforts have been made over the years to develop appropriate evaluation models that could use the irrigation parameters and variables to evaluate irrigation performance. Among these, the volume balance model is the basis for most design and field evaluation procedures. This has been proven with field and laboratory data. It allows quick and reliable definition of infiltration rates over the length of the field and it is easily extended to indications of uniformity and efficiency parameters (Walker and Skogerobe, 1987).

In response to the insufficient performance of existing irrigation system, focus was made on the performance evaluation of the schemes. This led to the establishment of performance criteria such as productivity, adequacy, equity, etc. However, in conducting performance of irrigation, more than one viewpoint exists. In addition, few of these criteria reflect the view of the farmers (Gowing et al., 1996). It is therefore essential that evaluation of the performance of surface irrigation systems be continued with a view to improve the performance of the systems and also to incorporate the view of the stake holders, i.e., the farmers in particular.

Different indices have been developed that are used for evaluating the performances of individual irrigation systems and for comparing the performances of different irrigation systems as well as farms. The type and number of indices (indicators) used for a particular situation depend on the level of details required for quantification, and on the number of disciplines selected for assessment. These may include, Agricultural, water use, economics, environment, management, physical etc. which are regarded as external indicators (Bos, 1997).

The common efficiency terms used for on-farm irrigation system evaluation (internal process indicators) include application efficiency, uniformity, storage efficiency and adequacy, and recently complementary terms such as runoff ratio, deep percolation ratio, are being applied (Jureims et al., 2001).

2.6.2.6. Conveyance Efficiency

The conveyance efficiency (Ec) is defined as the ratio between the irrigation water that reaches a farm or a field to that of diverted from the water source and is expressed in percentage (Odhiambo and Kranz, 2011)

The conveyance efficiency is the efficiency of water transporting canals or pipes in the field. It is mainly depends on the length of the canals, the soil type, permeability of the canal banks and the condition of the canals. In large irrigation schemes, more water is lost than in small schemes due to a longer canal system. When water is conveyed in pipes, mainly depends on pipe leakage and is usually close to 100 % for new systems.

According to Brouwer and Prins(1989), the conveyance efficiency for long unlined canals (>2000 m), the conveyance efficiency have been reported as 60, 70, 80% for sand, loam, and clay soil respectively; for medium length unlined canals (200-2000) as 70, 75, 85% for sand, loam and clay soil respectively; and for short canals (<200 m) as 80, 85 and 90% for sand, loam and clay soil respectively. The efficiency of lined canals has been reported in the order of 95% for all canal length.

2.6.2.7. Application Efficiency (Ea)

Water application efficiency provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. The objective is to apply the water and to store it in the crop root zone to meet the crop water requirement (Odhiambo and Kranz, 2011). After the water reaches the field supply channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the application efficiency. One very common measure of on farm irrigation efficiency is application efficiency. That asks how much of the water applied to the crop is actually used for crop growth or other beneficial uses. Losses from the field occur as deep percolation (depths greater than required depth) and as field tail water or runoff and reduce the application efficiency.

To compute application efficiency it is necessary to identify at least one of these losses (deep percolation and field tail water or run off) as well as the amount of water stored in the root zone. This implies that the difference between the total amount of root zone storage capacity available at the time of irrigation and the actual water stored due to irrigation be separated, i.e. the amount of under-irrigation in the soil profile must be determined as well as the losses (FAO,1989).

According to (Jurriens et al.,2001) the application efficiency is a common yardstick of relative irrigation losses. Losses from the irrigation system via runoff from the end of the field are indicated in the tail water ratio. Runoff losses pose additional threats to irrigation systems and regional water resources. Erosion of the top soil on a field is generally the major problem associated with runoff. The sediments can then obstruct conveyance and control structures downstream, including dams and regulation structures.

Kenneth (1988) indicated that attainable water application efficiencies varied greatly with irrigation system, type and management, and suggested that the attainable application efficiency for surface irrigation were in the order of 80-90%, 70-85% and 60-75% under basin, border and furrow type of system respectively. While FAO (1989) suggested 60 % attainable water application efficiencies for surface irrigation method. Also Norman(1999), said that a minimum value of the ratio of crop water demand to the actual amount of water supplied to the field of 0.6 (or irrigation efficiency of 60%) was included in the design of most surface irrigation systems to accommodate crop water needs and anticipated losses. Value below this limit would normally be considered unacceptable. Lesley (2002) suggested that it could be in the range of 50-80%. In general, according to (Michael1997), water application efficiency decreases as the amount of water applied during each Irrigation increases.

Drainage past the root zone is a particularly difficult component to measure and can be estimated by difference, i.e. other components are measured or estimated and the drainage is calculated as follows (Hodgson et al. 1990):

Deep percolation = **inputs** (irrigation water applied + effective rainfall) **-** **outputs** (crop water use + surface runoff + change in moisture)

All these components can then be used to estimate the application efficiency, the uniformity of the application, the adequacy of the application, and the effectiveness of the irrigation in meeting the target application. Reporting the efficiency derived from these values is meaningless without including the water balance used to calculate the preferred measure.

2.6.2.8. Water Storage Efficiency (Es)

According to Mishra and Ahmed (1990) and (FAO, 1989), the water requirement efficiency, is also commonly referred to as the storage efficiency. The requirement efficiency is an indicator of how well the irrigation meets its objective of refilling the root zone. This value is important when either the irrigations tend to leave major portions of the field under irrigated or where under irrigation is purposely practiced to use precipitation as it occurs. This parameter is the most directly related to the crop yield since it will reflect the degree of soil moisture stress. Usually, under-irrigation in high probability rainfall areas is a good practice to conserve water but the degree of under-irrigation is a difficult question to answer at the farm level.

The adequacy of an irrigation turn expressed in terms of storage efficiency, which is defined by (Jurriens et al. 2001) as the ratio between the storage depth and the required depth. The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application. In other words, it is defined as a ratio of the volume of water actually stored in the subject region to the volume of water that can be stored (Zerihun et al., 1997). Small irrigations may lead to high application efficiencies, yet the irrigation practice may be poor.

The concept of water storage efficiency is useful in evaluating this problem.(Jurriens et al.2001) express adequacy of irrigation turn in terms of storage efficiency and the purpose of an irrigation turn is to meet at least the required water depth over the entire length of the field. Conceptually, the adequacy of irrigation depends on how much water is stored within the crop root zone, losses percolating below the root zone, losses occurring as surface runoff or tail water the uniformity of the applied water, and the remaining deficit or under-irrigation within the soil profile following irrigation.

2.6.2.9. Distribution Uniformity

Distribution uniformity (Du) is a measure of how evenly water is applied during an irrigation event. This uniformity of application can have a considerable effect on crop yield and optimum water application. There are several interpretations in the literature, but a common measure for surface irrigation systems is to divide the average depth infiltrated calculated from the quarter of the field with the lowest infiltrated depths, by the average infiltrated depths. This is called the 'low quarter.'

When a field with a uniform slope, soil and crop density receives steady flow at its upper end, a water front will advance at a monotonically decreasing rate until it reaches the end of the field. If it is not dyked, runoff will occur for a time before recession starts following shutoff of inflow. Application uniformity concerns the distribution of water over the actual field. A number of technical sources suggest the Christiansen coefficient as a measure of uniformity. Others argue in favors of an index more in line with the skewed distribution. For example, Merriam and Keller (1978) propose that distribution uniformity be defined as the average infiltrated depth in the low quarter of the field, divided by the average infiltrated depth over the whole field.

The same authors also suggest an 'absolute distribution uniformity', which is the minimum depth divided by the average depth. Thus, the evaluator can choose one that fits his or her perceptions but it should be clear as to which one is being used. To get a complete picture of an irrigation performance you need to know more than just the indicators above, because these are average taken over the entire length of the field. Although different cases might produce the same results for Es and Ea their distribution patterns could differ. One indictor used to represent the pattern of the infiltrated depths along the field length is the distribution uniformity (Kruse, 1978) cited by (Jurrienset et al.,2001), which is defined as the minimum infiltrated depth (Dmin) divided by the average infiltrated depth (Da),

2.7. Crop Water Requirement

Crops will transpire water at the maximum rate when the soil water is at field capacity. (Broner,2003) reported that knowing seasonal crop water requirements is crucial for planning your crop planting mixture especially during drought years. Adequate data on irrigation water requirements of most crops is not available in developing nations of the world. This is one of the reasons why for the failure of large scale irrigation projects in most developing countries of the world (Adeniran et al., 2010).

The growth and yield of any crop is related to the amount of water used. The variable amount of water contained in a soil and its energy state are important factors affecting growth of plants (Hillel,2004). The accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapo transpiration (Nuha and Henery, 2000).

2.7.1. Reference crop Evapo Transpiration

To calculate reference crop evapo transpiration, the equation below (Allen *et al*. 1998) as recommended by the FAO has been in use.

$$\mathrm{ETo} = \frac{0.408\Delta(\mathrm{Rn}+\mathrm{G}) + \gamma\,\mathrm{X}\,\frac{900}{\mathrm{T}+273}\mathrm{U}_2\,(\mathrm{e_s} - \mathrm{e_a})}{\Delta + \gamma\,(1+0.34\mathrm{U}_2)} \text{--------------------------------------} 2.1$$

Where, ETo reference evapo transpiration (mm day^{-1}),

Rn-Net radiation at the crop surface (MJ m^{-2} day^{-1}), G- Soil heat flux density (MJ m^{-2} day^{-1}), T - Mean daily air temperature at 2m height (^{o}c), U_2-Wind speed at 2m height (ms^{-1}), es-Saturation vapour pressure (kPa), ea-actual vapour pressure (kpa), (es - ea)-Saturated vapour pressure deficit (kpa), Δ - slope vapour pressure curve ($kPa^{o}c^{-1}$), γ-psychometric constant ($kPa^{o}c^{-1}$).

Based on the comparative studies of the reference evapo transpiration methods and recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the FAO Penman Monteith equation has been adopted as the globally best performing method of estimating evapo transpiration (Smith *et al*., 1991). It is a method with strong likelihood of correctly predicting ETo in a wide range of locations and climates and has provision for application in data-short situations. The calculation can be done using CROPWAT model(Smith *et al*., 1991).

The use of the modified Penman-Monteith equation in irrigation practice requires empirical coefficients to modify in general to reduce but, sometimes to increase the estimates of reference crop evapo transpiration (Stanhill,2002). The limited availability of the full range of climatic data (particularly data on sunshine, humidity and wind) has often prevented the use of the combination methods and resulted in the use of empirical methods (which require only temperature, pan evaporation rate, or radiation data). This has contributed to the confusing use of different methods and conflicting evapo transpiration values.

To overcome this constraint and to further use of a single method, additional studies have been undertaken to provide recommendations on the using FAO Penman-Monteith method when no humidity, radiation or wind data are available. As a result, procedures are developed to estimate humidity and radiation from maximum/minimum temperature data and to adopt global estimated for wind speed. The availability of worldwide climatic databases further facilitates the adoption of values from nearby stations. Such procedures have proven to perform better than any of the alternative empirical formulas; and will largely improve transparency of calculated evapo transpiration values(FAO,1990)

Input data include monthly temperature (maximum and minimum), humidity, sunshine, and wind speed. Crop water requirements (ETc) over the growing season are determined from ETo and estimates of crop evaporation rates, expressed as crop coefficients (Kc), based on a well established procedures. The updated values of crop coefficients are determined from (Allen *et al*.,1998).

2.7.2. C**rop Evapo Transpiration**

Estimation of Etc is essential for computing the soil water balance and irrigation scheduling. ETc is governed by weather and crop condition (Smith, 2000). The specific wetting (irrigation) events are taken into account. Procedures to estimate ET+c have been well established by Doorenbos and Pruitt (1977), using a series of recommended crop coefficient values (Kc) to determine crop evapo transpiration (ETc) from reference evapo transpiration (ETo), This formula represents the single crop coefficient. Crop evapo transpiration (ETc) refers to evapo transpiration of a disease-free crop, grown in very large fields, not short of water and nutrient. Reference evapo transpiration (ETo) is calculated based on the FAO Penman-Monteith method.

2.8. Water Productivity

Concept of water productivity in agricultural production systems is focused on 'producing more food with the same water resources' or 'producing the same amount of food with less water resources'. Water productivity (WP) or water use efficiency (WUE) mainly refers to the ratio between output derived from water use and the water input (volume or value of water depleted or diverted) (Clement *et al*., 2011). The output could be biological goods or products such as crop (grain, fodder) or livestock (meat, egg, fish) and can be expressed in terms of yield, nutritional value or economic return. The output could also be an environment services or functions.

Water productivity is the ratio of crop output to water either diverted or consumed, the ratio being expressed in either physical or monetary terms or some combination of the two. Irrigation specialists have used the term water use efficiency to describe how effectively water is delivered to crops and to indicate the amount of water wasted. But this concept provides only a partial and sometimes misleading view because it does not indicate the benefits produced, and water lost by irrigation is often gained by other uses (Seckler *et al*., 2003).

According to (Dang *et al*., 2001) the water productivity is defined in three different ways. The water productivity per unit of evapo transpiration (WPET) is the mass of crop production divided by the total mass of water transpired by the crop and lost from the soil. The water productivity per unit of irrigation (WPI) is the crop production divided by irrigation flow. The water productivity per unit of gross inflow (WPG) is the crop production divided by the rain plus irrigation flow. Water productivity with reference to evapo transpiration (WPET) takes into accounts only water evaporated or transpired and is therefore focused on plant behavior whereas WPI and WPG include not only ET but also water used in other ways for crop products and water that are wasted.

2.8.1. Physical Water Productivity

Physical water productivity (WP) in agriculture refers to obtaining more crop production from the same amount of water. It takes account of water with yield which is defined as the ratio between the actual yield achieved and the total water use (TWU) (Pereira *et al*., 2009a; Yenesew and Ketema, 2009; Araya *et al*., 2011). However, other researchers defined WP as the ratio between actual marketable yield and actual seasonal crop water evapo transpiration (Kipkorir *et al*., 2002; Zwart and Bastianssen, 2004; Sisay *et al*., 2011).

To maximize crop water-use efficiency, it is necessary both to conserve water and to promote maximal growth. The farmer requires minimizing losses through runoff, seepage, evaporation and transpiration by weeds. The latter task includes planting high-yielding crops well adapted to the local soil and climate. It also includes optimizing growing conditions by proper timing and performance of planting and harvesting, tillage, fertilization and pest control. In short, raising water-use efficiency requires good farming practices from start to finish (FAO, 1997). (Mekonnen,2011) pointed out that to maximize crop water-productivity it is necessary to shift irrigation water management policy from 'maximum irrigation-maximum yield' to 'less irrigation-maximum CWP'.

2.8.2. Economic Water Productivity

Economic productivity is the gross or net present value of the product divided by the value of the water diverted or depleted, which can be defined in terms of it is opportunity cost in the highest alternative use (Sadeghi *et al*., 2010). It gives an indication of how much value is obtained from the use of water. Based on the scale and purpose of the experiment, researchers used different numerator and denominator to express economic water productivity (EWP). (Rodriguez and Pereira 2009) defined it as the ratio between the value of actual crop yield and the total water use, in birr/m3.

2.9. Agronomy of Crops Studied (Onion)

Onion (Allum cepa) is believed to have originated in the near east. The crop can be grown under a wide range of climates from temperate to tropical (Doorenbos and

Kassam, 1996).Onion is one of the most important vegetable crops produced in Ethiopia. Among different varieties, Bombay Red is the most widely used as a cash crop by the farmers in the rift valley areas (Aklilu, 1997). Onion is a cool season biennial monocot with a prominent bulb, hollow cylindrical leaves and a strong odor when bruised. The optimum temperature for plant development varies between 13^0C and 24^0C, while, for raising seedlings, it requires up to 25^0C and generally require high temperatures for bulbing and curing (Kalb and Shanmugasundaram, 2001). Onions grow on a variety of soils ranging from sand to clay loams. However, they prefer loamy soil that is fertile, well drained and high in organic matter, with a preferable PH range of between 6.0 and 8.0 (Olani and Fikre, 2010). Onions do not thrive in soils below pH 6.0 because of trace element deficiency, or occasionally, aluminum or manganese toxicity. Onions could be produced on slightly alkaline soils, but are sensitive to soil salinity. According to the (Andreas and Karen 2002), a soil salinity level of 4.3 dS/m or more could decrease the yield of onion by up to 50%. Onion plants usually require substantial amount of nutrients. Thus, fertilizer application followed the recommendation for Awash Melkassa area; at the rate of 100 kg/ha Urea and 200 kg/ha DAP.

The crop requires frequent (every 2 to 4 days), light irrigations which are timed when about 25% of available water in the first 0.3 m soil depth has been depleted by the crop, and as such, requires 350-550 mm water throughout its production season. The crop coefficient (Kc) relating reference evapo transpiration to water requirements for different development stages after transplanting are, for the initial stage 0.4 to 0.6 (15 to 20 days), development stage 0.7 to 0.8 (25 to 35 days), mid season stage 0.95 to 1.1 (25 to 45 days) and late season stage 0.75 to 0.95 (35 to 45 days) (Doorenbos and Kassam, 1996).

Managing the time and amount of applied irrigation is critical to achieve optimum yield and quality (Andreas and Karen, 2002). Light and frequent irrigations are required through furrow irrigation systems throughout the growing season for several reasons: root system is shallow; therefore, very little water is extracted from a soil depth deeper than 0.6 m, and most is from the top 0.3 m. This indicates that upper soil areas must be kept moist to stimulate root growth. Rates of transpiration, photosynthesis and growth are lowered by even mild water stress (Voss and Mayberry, 1997).Onions usually harvested from 100 to 140 days after transplanting (Brewster, 1990) when 80% of the bulbs become completely mature, which is evident by the collapse of 20 to 50% of the neck tissue and falling of the tops. A good bulb yield can be 35–45 ton/ha, and the water productivity ranges from 8–10 kg/m3 (Doorenbos and Kassam, 1996; Kalb and Shanmugasundaram, 2001).

3. MATERIALS AND METHODS

3.1. General Description Of The Study Area

Jimma Geneti is one of the woreda in Oromia Region of Ethiopia which is the part of Horo Guduru Wollega Zone. Jimma Geneti is bordered on the South East by Bako Tibe and Jimma Rare, on the west by Horo and Gudeya Bila, on the North Horo and East by Guduru. The Administrative center of this woreda is Hareto. It has about 12 rural and 2 urban kebeles. The source of irrigation water for the scheme was Jidda River by diversion. The scheme was constructed by Agricultural Growth Program(AGP) in 2015 collaborating with Ethiopian government to improve the living standards of the farmers living around the project area by enabling them to produce year rounded production irrespective of rainfall availability.

3.1.1 Location and Accessibility

The project is located in Oromia regional state, Horo Guduru Wollega zone, Jimma Geneti district in Damu Gembo (Jidda) peasant association at about 38km from Shambu town (Zone and district capital). It is at 290 Km from Addis Ababa out of which 250Km is asphalt road and 40Km all weather road and 1.2Km dry weather access that need clearance. The area is accessible from Shambu via gravel road of 40 km and dry weather access of about 1.2 km that needs maintenance. The headwork located at North-East direction (GPS location UTM 37P 0295644m E, 1031737m N) with projection system UTM and datum ADINDAN. The area is categorized under sub-tropical climate. Farm lands dominate the land use of the area and it has fair vegetation cover. The soil of the area is clayey in texture and dark to dark brown in color. It is deep, slightly expansive, firm and with low infiltration rate and high water holding capacity. There are attempts made by local community to expand traditional irrigations around the project area. The area needs good soil and water management for diversification of crop production through modern irrigation. Also drainage of existing farm land is very important to sustain the soil structure. The area is on average elevated to 2245m.a.s.l. The project area receives mean annual rainfall is estimated to be about 1517mm. The study has covered gross area of about 110 hectares(OWMEB Design document). Location of the study area was as shown on figure 1 below.

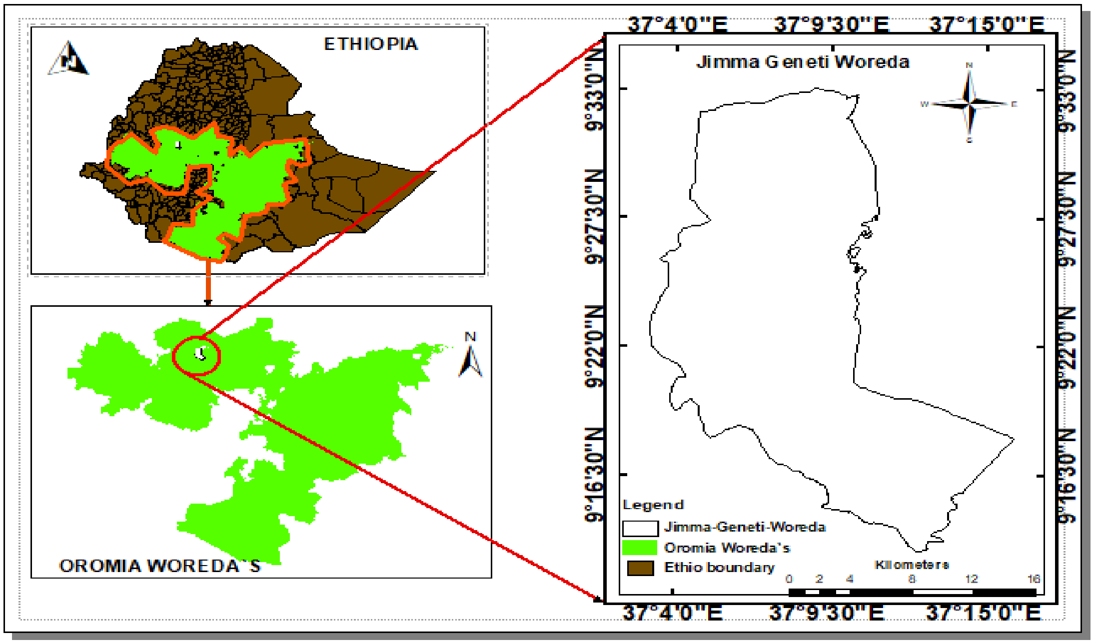


Figure 3.1: Location of the study area

3.1.2. Description of Soil Mapping Units

The soil of the study area was derived from Abay Basin shape file. Based on the soil classification six types of soil were identified. The major soil groups identified in the study area are: Eutric cambisoils , Eutric planosols, Chromic vertisols, Vertic lumisols, vertisols and Eutric Vertisols as shown in Figure 3.2.

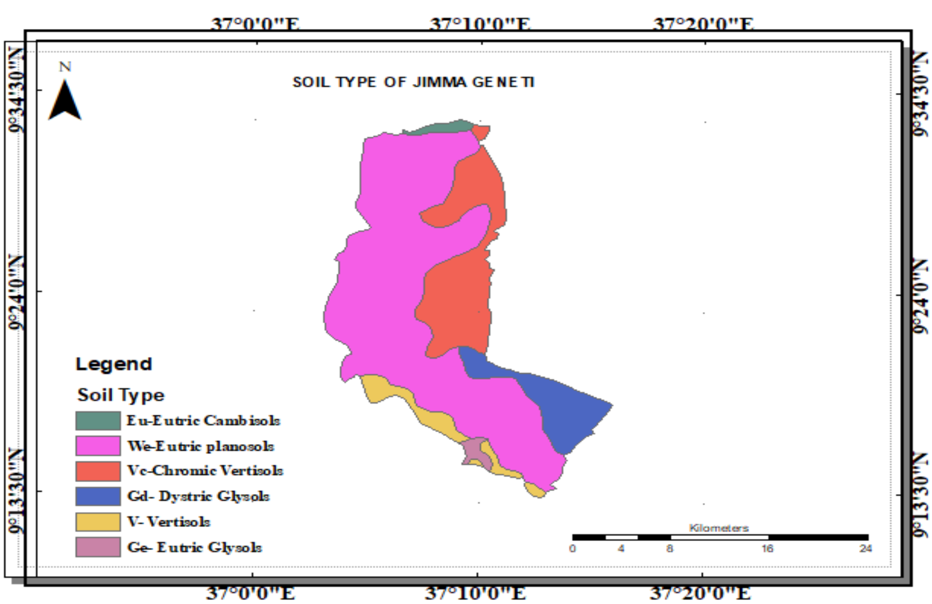


Figure 3.2: Soil Mapping of the study area

3.1.2.1. Topography

The flat to gentle sloping topography of the study area makes it suitable for irrigation, drainage and mechanization. Some gentle sloping (4-5% slope) areas at the foot of hills and mountains are not suitable for surface irrigation because they are not suitable for leveling due to the very shallow soil depth. They can, however, be used as infrastructure placement or for pasture development by pressurized irrigation systems.

3.1.2.2. Agriculture

Agriculture is the major economic activity in the rural area, mixed farming system being a common practice in all agro-climatic zones (highland, midland and lowland). Accordingly, crop production and livestock are the main source of livelihoods of rural population

i. Crop Production

The common crops produced by farm households in the area include maize,Teff, Noug, finger millet and sorghum. Farmers also grow vegetables such as onion, tomato, potato and pepper by using small scale irrigations. In the area, the major crop is maize, which is mainly known by high productivity, especially hybrid maize (BH-660).

Table 3. 1: Types of crops in Jimma Ganati Wereda

No.	**Type of crop**	**Area in ha**	**Production(Qt)**	**Yield(Qt/ha)**
1	Maize	4334	255,706	59
2	Teff	4220	59,080	14
3	Noug	638	3,828	8
4	Sorghum	3142	81,692	26
5	Oat	37	592	16
6	Pepper	450	337.5	0.75
7	Cabbage	103	1,236	12
8	Pea	724	8,688	12
9	Bean	1972	139755	5.50
10	Lentils	33	297	9
11	Potato	1980	25740	80
	Total	**17,633**	**576654.5**	

Source: Jimma Ganati district office of agricultural development and Damu Gembo P.A development center, 2012

3.1.2.3. Land Use

The selected command area of the project spreads over two kebeles of Horo Guduru Wollega Zone of Oromia Administrative Region. Major project command area falls under Jimma Geneti Wereda about 2247m asl.

Table 3. 2. Land Use of Jimma Geneti Woreda

Land use type	Jima Geneti		Damu Gembo, Project Kebele	
	Area (ha)	%	Area (ha)	%
Arable land	27,708.1	61.2	1554	73.86
Forest land	5,647.23	12.47	447	21.25
Bare Land	551.34	1.22	12	0.57
Wetlands	2,000.24	4.41	10	0.47
Grazing land	3,965.5	8.76	25	1.19
Water bodies	975.87	2.15	12	0.57
Settlement Land	4,436.46	9.79	44	2.09
Total	45,284.74	100	2104.0	100.0

Source: (Jimma Geneti Woreda, A. Hailu.*et al*, 2020)

This includes 61.2% cultivated land, 12.47% Forest land, 1.22% Bare Land, 8.76% grazing land, 4.41 wetlands 2.15% Water bodies and 9.79% Settlement lands.

The land use data of the Jimma Ganati district indicates that a very insignificant proportion of the arable land is under cultivation, amounting to 73.86% of the total cultivable land of the district. The main cultivated land is found in the temprate where 80% of the district’s rural population resides.

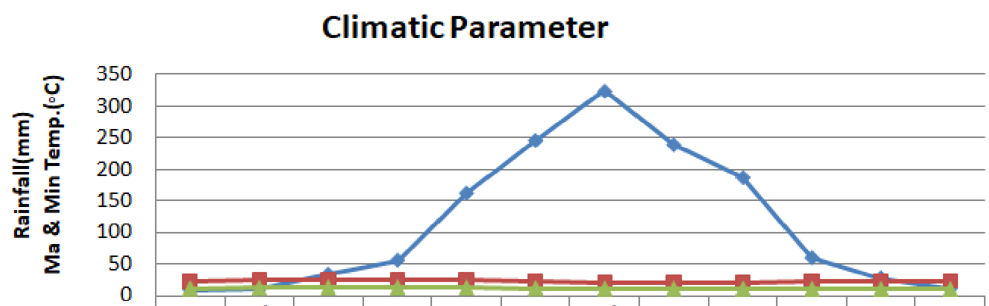
Area and production wise, the most dominant crops are onion, maize, tomato, and pepper, both as a cash crop and staple food for most of the people, both in the district & the project area. From the design document (OWMIB).

3.1.2.5. Climate

For this study, 20 years meteorological data (1999 to 2019) were taken from National meteorological service, Shambu branch for Shambu meteorological station used to compute the crop water requirement and the irrigation water demand. Such data include; Temperature (maximum and minimum) relative humidity, sunshine hours, wind speed and rainfall. The mean monthly minimum and maximum temperature in the project area varies from 10.5^0C to 24.53^0C respectively. The mean minimum temperature is recorded in November and the maximum is recorded in February. March and April are the hottest months of the year in the project area. The highest rainfall occurs in July and August; while the lowest rainfall occurs in January.

The rain fall distribution in the study area showed an unimodal pattern. The minimum and maximum rainfall amount occurs in the month of January is 8.7mm and June 324.2mm respectively (Appendex Table 7.6). The irrigation Project had an average total rain fall of 79mm. Conversly the average total annual effective rain fall amount of the scheme was 78.1mm (Appendex Table 7.12). The study area is characterized as moisture stress area. Hundred percent of the respondant revealed that the rain fall was insufficient for crop production for the last years in the study area. Despite the variability of rain fall distribution in time and space, the amount of rain fall recieved in Belg season (March–june) has siginificant impact for crop production in the irrigation season. In addition, it has an advantage to minimize confilict that may arise due to water shortage in critical irrigation months. Hence, this effective rain fall during Belg season also contributed to support the crop water demand in the main irrigation seasons.

The methodology used to determine climatic characteristics in the project area is by analyzing the nearby meteorological stations. Meteorological data for all the observed climatic elements computed using short recent available records from shambu and Fincaa stations.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall(mm)	8.7	10.9	33.1	55.2	162.2	245.8	324.2	238.9	186.8	59.1	27.6	10.7
Max.Temp(◦C)	23.13	24.42	24.53	24.2	24	21.87	20.1	19.9	20.9	21.6	22.7	23.3
Min. Temp(◦C)	11.08	12.45	13.28	13.28	12.85	11.88	11.46	11.4	11.24	10.99	10.75	10.5

Figure 3.3 Climatic Parameter

3.2. Characterization of the Project

Characterization of the scheme was done by looking into the secondary information from design documents, field observation and canal measurements. Main and branch canals were described in terms of their discharge, canal dimensions, and length of flow and functionality of the scheme elements as well as analysis of number of civil works completed as per the design or not.

Characterization of Jidda Irrigation Project is mostly resource characterization such as water and soil resources. The water distribution and management system and the existing conditions of constructed structures were also assessed mostly depending on the main canal. Because, the project is huge and it takes time to take the whole inventory to characterize the entire project.

3.2.1. Scheme Characterization

i. Overtopping

Water in a canal may rise unexpectedly due to several reasons, the incoming flow through the canal off take may be much greater than the canal capacity; obstacles such as stones, blocks or plant growth in the canal, dam up the water outlets from a canal closed which should be open; rain or other water, may be draining into the irrigation canal; or farmers may make temporary weirs to raise the water level.

If no action is taken, the water level can reach the top of the canal banks and overtop. Overtopping causes erosion of the canal banks and may lead to serious breaches. It can be avoided by improving the operation of the system. Discharges should be limited and gates should only be closed and opened according to the planned schedule. To prevent overtopping, this can happen even in the best irrigation systems.

ii. **Sedimentation on irrigation canals**

Sedimentation affects the operation of irrigation schemes by reducing discharge capacities and raising water levels. Sediment deposits have to be removed periodically to maintain irrigation supplies. In many schemes, de-silting costs are excessive, and in some, the sediment settles faster than it can be removed for maintenance. These results in problems of undersupply, inequality, and an inevitable decline in the command area that can be irrigated (Chancellor *et al*., 1996; Philip and Atkinson, 1998; Sahabrabudhe, 2000).

Materials which were used to conduct the study:

i. Weight balance: used to measure weight of soil moisture (i.e. at wet and dry condition of soil).

ii. Oven dry: oven was used by high-forced thermal convection (105˚C) to dry soil sample. Discharge was determined by using velocity-area method, to perform these, the following materials were used on the study:

iii. Tape meter: was used to measure the length of the canal and area of field plot.

iv. Stop watch: to know the time taken water passing through the partial flume.

v. Partial flume: used to measure depth of water or discharge at field level.

vi. GPS: was used to measure area of currently irrigated land and coordinate's of each measurement points in the study area.

vii. Current meter: used to measure flow velocity in the conveyance system.

viii. Software GIS(Arc GIS), Cropwat, Google earth, AutoCAD

3.3. Methodology

3.3.1. Data Collection Method

For this study, data was collected and analyzed starting from Sebtember 2020 to January 2021 through direct field measurement, regular visits and observations were made to assess the method of water applications and practices related to water management at the study sites for selected farmers from head, middle and tail reach of irrigation system as well as from legal governmental organizations. These data were both primary and secondary as discussed below.

3.3.1.2. Primary Data

The primary data are canal water flow measurement of the field area, canal cross-sections data, dimension of the farm structures, measurement of depth of water applied to the field and focus or Interview with water user Association of irrigated area. The flow data was including amount of irrigation water diverted from the sources, conveyed or delivered to targeted location and distributed to field off take canals. The flow was measured by using Floating-area method. Dimension of canal cross-section and farm structures at different measuring stations was measured by measuring tape. In addition, currently actual irrigated area was also measured from direct measurement of the area by GPS and uses it by comparing with data that gathered from field of irrigated farmers and District Irrigation Development Authority office experts.

i. Estimating the Discharge

The aim of good irrigation management is to obtain a correct flow division within the canal network and over the fields. This means that discharges in canals should meet the demand for water from the farms. A poor flow division may result in discharges being too high in some canals and too low in others, and could lead to water disputes between farmers. To achieve sufficient and equitable delivery of water to the fields it is useful to know the discharge in the canal. The discharge in a canal can be measured with or without a discharge measurement structure. Method described here is the floating method. This method is a quick and cheap way to estimate discharge in a canal. However, this method is not very accurate and errors of at least 10% can be expected. The method consists of estimating the average flow velocity (V), and measuring the area of the cross-section, called the 'wetted cross-section' (A). The discharge (Q) can be calculated by the following formula:Q = V A

Where: Q is the Discharge in m^3/s; V is the Average Flow Velocity in m/s; A is the area in m^2 of the Wetted Cross-section.

To estimate the average flow velocity, the flow velocity of the water at the surface, the surface velocity, Vs, is first determined. The surface velocity is determined by measuring the time it takes for a floating object, such as a stick, a bottle or a coconut, to travel through a previously measured distance of, say, 10 or 20 meters along the canal. The floating object should be placed in the centre of a canal and the time measurement should be repeated several times to avoid mistakes. The stretch of canal used for measurement should be straight and uniform, in order to avoid changes in the velocity and in the area of the cross-section, because any such variation reduces the accuracy of the velocity estimation. To compute the surface velocity, Vs, the selected length, L, is divided by the travel time, t: Vs = L / t

Where: Vs is the Surface Velocity in meters per second (m/s); L is the distance in meters between points A and B; and t is the Travel time in seconds between point A and B.The surface velocity must be reduced in order to obtain the average velocity, because surface water flows faster than subsurface water. For most irrigation canals this reduction factor is about 0.75. The average velocity is therefore, found from V = 0.75 Vs, Where V is the Average Flow Velocity in m/s; 0.75 is a constant, the Reduction Factor; and Vs - is the surface velocity in m/s found from the previous calculation.

Summary of infrastructure condition (from asset survey) Scheme/system level Percentage of structures defective, Percentage of structures requiring maintenance, .Percentage of structures requiring improvement and Percentage of canal length defective and so on.

Additionally, some sort of information regardless of Jidda Irrigation had been made among the farmer of informal groups; Farmers' views on responsibility for canal maintenance, the responsible for the maintenance whether OIDA or farmers themselves (WUA), Farmers reporting a contribution to maintenance, farmers' perceptions of water supply and system operation capacity of farmers to carry out repairs/maintenance.

ii. **Field observation and Capturing the current situation of irrigation systems**

The first activity was to walk through the farms and along the canals in order to observe the existing situation of the scheme. The objective of direct field observation is to obtain and document an overview of water conveyance, water distribution systems, nature of landholdings, management practice, healthy of headwork and on farm structures in the farming systems. The main canal, the secondary canals, tertiary canals and all of their structures have been inspected and documented. Moreover, the field survey enabled measurement of some components such as dimensions of intakes, sizes of main canal and tertiary off take. Field survey is of course an unavoidable activity in performance evaluation as it provides lots of information in a relatively short period of time (Zeleke, 2015). After assessing and handling the current status of the scheme, plotting the overall layout of irrigation system (main, secondary and branch canal alignment, position of irrigation structures etc.).

iii. Flow Measurement

To determine the amount of water applied by the irrigators to the field, during an irrigationevent, three inches partial flumes were installed at the entrance of test plot. Frequent readings were taken when the farmers irrigate the test plot. Irrigation was continuing until the farmers' thought that enough amount of water is applied to the field. When the irrigator completed irrigating the test plot, the average depth of irrigation water passing through the flume and the respective time were recorded for the sizes of test plot being irrigated. The discharge was computed using equation.

Then, the discharge was calculated using the following equations (Walker and Skoerboe, 1987):

$$Q_f = C_f * W * h_u^{nf} = 0.1765H^{1.547} \text{ --- } (3.1)$$

Where: Q_f - is discharge for free flow condition; W - is throat width; h_u - is upstream heads of parshall flume; C_f - is free flow coefficient and n_f - is exponents for free condition. And the depth of water applied was computed from discharge, cut-off time and area irrigated. The time of cut-off was the time farmer's decide that enough water would have been applied to their fields.

The amount of depth of water per furrow was computed as follows:

$$D = \frac{QavTapp}{100A} \quad \text{---}(3.2)$$

$A = W*L\ (m^2)$

Where: D- depth of water applied (cm), A-area over which water is applied (m^2), L-furrow length (meters), W - furrow width (meters), T_{app} - application time (sec), Q_{av}-average discharge rate (lit/sec).

To measure the cross section of the furrow, the width of the furrow was determined by selecting three furrows per test plot. The width of each furrow was measured at three points per furrow (top, middle and end) dividing into seven equal segments, and then the average width was calculated. The depths of each segment of the furrow were measured. The area of each segment is the product of the width of segment and its average depth. The areas of the segments are summed to determine the total cross sectional area.

iv. **Farrow evaluation through Advance and Recession Time Measurements.**

In order to measure the behavior of advance and recession curves, furrows on test plots were identified. Wooden posts were placed uniformly along the flow direction at five meters interval. The time it takes for the water front to reach wooden post (advance time) and the time it takes for the water to recede at each wooden post (recession time) was taken and recorded. The opportunity time (the difference between the advance and recession time) at each of the wooden posts was calculated.

v. **Field Layout, Crop Selection and Experimentation**

In order to evaluate the irrigation water use efficiency of farmers at field level and to compare each other in the scheme, nine farmers' fields were selected three of each from the head, middle and tail end water users of the irrigation scheme with respect to water resource. The criteria for selection of a plot were location (head, middle, and tail), their similarity with water management practices, crop grown and willingness of the farmers to collaborate. A total of nine red onion growers' farmers were selected. The reason for the selection of Onion was that it is the dominant and representative crop in which most farms are covered with it because of its production potential and good market in the area.

Table 3.3. Depicts the layout of nine selected fields, grown with onion crops. The selected fields represent from head, middle and tail of the irrigation command area in reference to the water resource.

Table 3. 3: Layout of nine-selected farmer's fields

Head ↓	Middle ↓	Tail ↓
P-1	P-4	P-7
P-2	P-5	P-8
P-3	P-6	P-9

3.3.1.3 Secondary Data Collection

For each of the selected irrigation schemes, secondary data were collected from the Jimma Geneti district Agricultural and Rural Development Office and irrigation offices at regional and zonal levels. Furthermore, research centers and NGOs of the agricultural sectors were visited periodically to gather further information like feasibility study documents, production costs, investment cost and other relevant information. The secondary data included soil data, crop data, actual area, Total yields, farm gate prices of irrigated crops, area irrigated per crop per season, production cost per season, incomes generated by the irrigation associations and cropping pattern. Climatic data of the irrigation schemes were collected from the nearby metrological station which was further incorporate with soil and crop data to estimate crop water requirement by Cropwat model.

3.4. Scheme Performance Evaluation

Performance evaluation was carried out using different resource characterization and efficiency indices. And the results are presented and discussed.

3.4.1. Technical Performance Evaluation

The performance of farm irrigation is determined by the efficiency with which water is diverted, conveyed, and applied; and by the adequacy and uniformity of application in each field on the farm. Among the factors used to judge the performance of an irrigation system or its management, the most common ones are efficiency and uniformity. These parameters have been subdivided and defined in a multitude of ways as well as named in various manners.

Common performance indicators defined by Kloezen and Garces-Restrepo(1998), based on literature include conveyance efficiency, application efficiency, and storage efficiency.

A) Water Conveyance Efficiency (Ec)

This is the loss, which occurred through the conveyance systems from the diversion point to the field where the water is to be used. Notably, it is the ratio between water received at the inlet to the field and the amount of water diverted from the source and computed as:

$$Ec = \frac{\mathrm{Wf}}{\mathrm{Wd}} * 100 \qquad (3.3)$$

Where: Ec - water conveyance efficiency (%); Wf- amount of water delivered to the farm; Wd- amount of water Pumped/diverted from the source.

The conveyance efficiency was measured on the main canal by measuring discharges at two different points. The discharges were calculated from the velocities of the water flowing in the main canal using floating materials. The method of discharge measurement is called floating method as floating materials being used for velocity measurement. The discharge measurement was conducted in the upper position of the main canal. Floating material was put on the upper end of the canal section and the time it took to reach the marked section of the same canal was registered. This test was replicated five times and the average time it took was taken to calculate the discharges. The cross sectional area of the canal was also estimated by measuring the average depth and width of the same canal section. The average velocity and the rate of flow (discharge) were calculated by dividing the distance with the average time, and by multiplying the cross sectional area with the average flow velocity, respectively. Then continuity equation (Q = A x V) was used, where, Q is the discharge (m^3/sec), A, the cross sectional area of the canal (m^2) and V, the average flow velocity (m/sec).

The second measurement was taken at a fixed distance above the downstream end of the main canal. The same procedure was followed to that of the upper parts of the canal to estimate the discharge at the outlet (the downstream end) so that the amount of conveyance loss was known and the conveyance efficiency was determined. The measurements for both positions were taken twice.

B) Application Efficiency Estimation

The evaluation of the application efficiency was made on nine selected farmers' fields of irrigation scheme. Water applied to the field was measured by installing 3 inch partial flumes at entrance of selected farmer's field when fields were being irrigated. Before proceeding to the measurement, it was located in straight section of flow. The flow rate was obtained by taking consecutive measurements of water depth, because it has been established that depth varies proportionally with flow. To determine the amount of water applied to the field, water depth passing through the flume to the field and its respective time intervals were recorded with the size of the field being irrigated. Since it is free flow, only upstream measurement point was used. The measurement point was located within the 2/3 portion of the converging section from the beginning of the throat section. Then, the discharge was calculated using the following equations Walker and Skoerboe, (1987):

$$Q_{f} = C_{f} * W * h_{u} n_{f} = 0.1765H^{1.547} \text{ --(3.4)}$$

Where: Qf - is discharge for free flow condition; W- is throat width; hu - is upstream heads of partial flume; C_f - is free flow coefficient and n_f -is exponents for free condition. And the depth of water applied was computed from discharge, cut-off time and area irrigated.

The time of cut-off was the time farmer's decide that enough water would have been applied to their fields.

The application efficiency of each field was calculated using equation (FAO, 1989; Michel 2008):

$$Ea = \frac{Ws}{Wf} * 100 \text{ ---(3.5)}$$

Where: Ea -the application efficiency (%); Ws-water stored in the root zone (mm);W_f-Water applied to the field (mm).

The depth of water stored in the root zone of selected field was determined from the soil moisture content before and after irrigation by gravimetric method. The depth of water applied to the field was estimated by dividing the average total amount of water applied to the field by the area irrigated. The depth of water retained in root zone was calculated using equation (Michel, 2008)

$$D = \sum_{i=1}^{n} \frac{(Mafi - Mbi)}{100} * AiDi \text{--- (3.6)}$$

Where: d - depth of water retained into root zone of the soil (cm), M_{afi} and M_{bi} moisture contents in the i^{th} layer of the soil after and before irrigation (% weight basis), A_i -bulk density of the soil in the i^{th} layer, D_i -depth of the soil i^{th} soil layer within the root zone (cm) and n - number of layers in the root zone.

C) Storage Efficiency Estimation

Storage efficiency was measured using equation (3.7) as recommended by (Allen *et al.*, 1998 and Michel, 2008):

$$Es = \frac{Ws}{Wn} * 100 \text{ ---(3.7)}$$

Where, Es - storage efficiency (%), Ws - water stored in root zone during irrigation (mm), Wn - water needed in root zone prior to irrigation (mm).

The depth of water retained in the soil compartments of the root zone was computed by equation (3.6) and the water needed in the root zone prior to irrigation is estimated by the equation(3.8) given by (Allen *et al.*, 1998):

$$Wn = \sum_{i=0}^{n} \frac{\theta FC - \theta BI}{100} i * Di \text{---(3.8)}$$

where, W*n*- the depth of water needed in the root zone prior to irrigation (mm), θFC and θBI-soil moisture content at field capacity and moisture content of the soil before irrigation in volume percent, respectively and *Di*- the depth of soil profile in root zone (mm).

D) Distribution Uniformity Estimation

Distribution uniformity was measured using the distribution uniformity index as proposed by James (1988):

$$Du = \frac{Zmin}{Zav} * 100 \quad \text{--} (3.9)$$

Where, DU- distribution uniformity coefficient, in %; Zmin - the minimum depth infiltrated at the ith point in mm; Zav - the mean depth infiltrated in mm and computed as

$$Zav = \sum_{i=1}^{n} \frac{Zi}{N} \text{---}(3.10)$$

N - Number of points where samples were taken

FAO (1992) suggested that the average distribution efficiency DU of 65% as sufficient and DU of 30% as poor.

E) Christiansen Uniformity Coefficient (CUC)

The uniformity of application was evaluated using Christiansen uniformity coefficient (Jurriens *et al.*, 2001). This is given as:

$$UC = 100\% \left(1- \frac{\text{Av.Devation from Av.Depth of application}}{Overall\ Average\ depth\ of\ Application}\right)$$

F) Determination of Deep Percolation Ratio (DPR)

Since the furrows are closed end, runoff ratio is neglected. The loss of water through drainage beyond the root zone is reflected only in the deep percolation ratio that expresses the ratio between the percolated water beyond the root zone to the volume of water applied to the field. Also the evaporation from the soil is marginal and can be neglected because, it is only a short period after irrigation. Therefore, deep percolation ratio was calculated for selected nine test plots as:

$$DPR = \frac{\text{Volume of deep percolation in M3}}{\text{Volume of water applied to the field}} \text{--------------------------------}(3.12)$$

3.4.2. Economic Performance Evaluation

An economic efficiency analysis is a systematic way to compare yield which would be produced with the total cost for the production. Two principal value measurement parameters were used in this analysis. To determine the total net contribution (net benefits) of a project to farmers, the net present worth (NPW) was used to provide a systematic ranking of alternatives and it was computed as(IWMI)

$$\mathrm{NPW} = \sum[(\mathrm{Bt} - \mathrm{Ct})/(1 + \mathrm{r})^{\mathrm{t}}] \text{ ---------------------------------------}(3.13)$$

Where: Bt and Ct- benefit and cost in a year respectively, and r-social discount rate.

To compare the benefits to costs, the Bt/Ct ratio formula was used as:

$$\mathrm{Bt/Ct\ ratio} = \sum[\frac{Bt}{(1+r)^t}]/\sum[\frac{Bt}{(1+r)^t}] \text{ ---------------------------------------}(3.14)$$

If Bt/Ct ratio is more than 1, the present value of benefit is greater than the present value of costs and project is economically efficient use of resources, assuming that there is no lower-cost means for achieving the benefits.

3.4.2.1. Crop Water Requirement

Crops will transpire water at the maximum rate when the soil water is at field capacity. (Broner, 2003) reported that knowing seasonal crop water requirements is crucial for planning your crop planting mixture especially during drought years. Adequate data on irrigation water requirements of most crops is not available in developing nations of the world. This is one of the reasons why for the failure of large scale irrigation projects in most developing countries of the world (Adeniran *et al*., 2010).

The growth and yield of any crop is related to the amount of water used. The variable amount of water contained in a soil and its energy state are important factors affecting growth of plants (Hillel, 2004). The accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapo transpiration (Nuha and Henery, 2000).

3.4.2.2. Reference Crop Evapo Transpiration

To calculate reference crop evapo transpiration, the equation below Allen *et al*. (1998) as recommended by the FAO has been in use.

$$ETo = \frac{0.408\Delta(Rn + G) + \gamma \, X \frac{900}{T+273} U_2 \, (e_{s-} e_a)}{\Delta + \gamma \, (1 + 0.34 U_2)} \text{-----------------------------}(3.15)$$

Where, ETo- reference evapo transpiration (mm day^{-1});

Rn - Net radiation at the crop surface (MJ m^{-2} day^{-1});

G- Soil heat flux density (MJ m^{-2} day^{-1});

T- Mean daily air temperature at 2m height (^{o}c); U_2 - Wind speed at 2m height (ms^{-1}); e_s - Saturation vapor pressure (kPa); e_a - actual vapor pressure (kpa);

(e_s - e_a)- Saturated vapor pressure deficit (kpa);

Δ- slope vapor pressure curve (kPa $^{o}c^{-1}$); γ - psychrometric constant (kPa $^{o}c^{-1}$).

Based on the comparative studies of the reference evapo transpiration methods and recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the FAO Penman Monteith equation has been adopted as the globally best performing method of estimating evapo transpiration (Smith et al., 1991). It is a method with strong likelihood of correctly predicting ETo in a wide range of locations and climates and has provision for application in data-short situations. The calculation can be done using CROPWAT model.

The use of the modified Penman-Monteith equation in irrigation practice requires empirical coefficients to modify in general to reduce but, sometimes to increase the estimates of reference crop evapo transpiration (Stanhill, 2002). The limited availability of the full range of climatic data (particularly data on sunshine, humidity and wind) has often prevented the use of the combination methods and resulted in the use of empirical methods (which require only temperature, pan evaporation rate, or radiation data). This has contributed to the confusing use of different methods and conflicting evapo transpiration values.

Input data include monthly temperature (maximum and minimum), humidity, sunshine, and wind speed. Crop water requirements (ETc) over the growing season are determined from ETo and estimates of crop evaporation rates, expressed as crop coefficients (Kc), based on a well established procedures. The updated values of crop coefficients are determined from Allen et al. (1998).

3.4.2.3. Crop Evapo Transpiration

Estimation of ETc is essential for computing the soil water balance and irrigation scheduling. ETc is governed by weather and crop condition (Smith, 2000). The specific wetting (irrigation) events are taken into account. Procedures to estimate ETc have been well established by Doorenbos and Pruitt (1977), using a series of recommended crop coefficient values (Kc) to determine crop evapo transpiration (ETc) from reference evapo transpiration (ETo), as follows:

$$ETc = Kc * ETo$$

(ETo) is calculated based on the FAO Penman-Monteith method.

3.4.2.4. Yield Data Collection

To assess the overall impact of water distribution and performance parameters on yield, the yield of shallot was collected separately from head, middle and tail end plots. Water use efficiency was then calculated. Shallot was harvested by hand from the three ridges of all plots. The yield of the shallot was collected from three ridges by sampling from each selected plots. This was done dividing the ridges into three equal parts along its length. Then yield was collected from each plot in the fields and weighed. The total yield obtained from the test plot was also measured.

3.4.2.5. Estimation of Water Productivity

To compare the relative water productivity of the farmer`s field at three locations (head, middle and tail), yield of the Onion was collected from each of the nine selected fields. Then the collected yield from each field was weighed. After determining the amount of water applied and estimating amount of water consumed by crop through process of evapotranspiration in a season, the physical Water productivity (CWP) was computed as (Zwart and Bastiaanssen, 2004) by using the following equations.The following is the method as used by IWMI.

$$\text{CWP}\ \left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\text{Total bulbs produced}\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{ETc}\left(\frac{\text{m3}}{\text{ha}}\right)} \text{--(3.16)}$$

$$\frac{\text{Water productivity}}{\text{water applied}}\left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\text{Yield(kg)}}{\text{water divertied to the field(m3)}} \text{------------------------(3.17)}$$

Where; CWP is physical water productivity

The local market price at Sibu sire during the time of harvest was used to evaluate water productivity on monitory units. Economic water productivity (EWP) was determined by dividing the gross benefit to volume of water consumed.

$$\text{EWP (Birr/ m3)} = \frac{\text{Gross Benefit}(\frac{\text{Birr}}{\text{ha}})}{\text{ETc}(\frac{\text{m3}}{\text{ha}})} \text{---(3.18)}$$

3.5. General Frame work

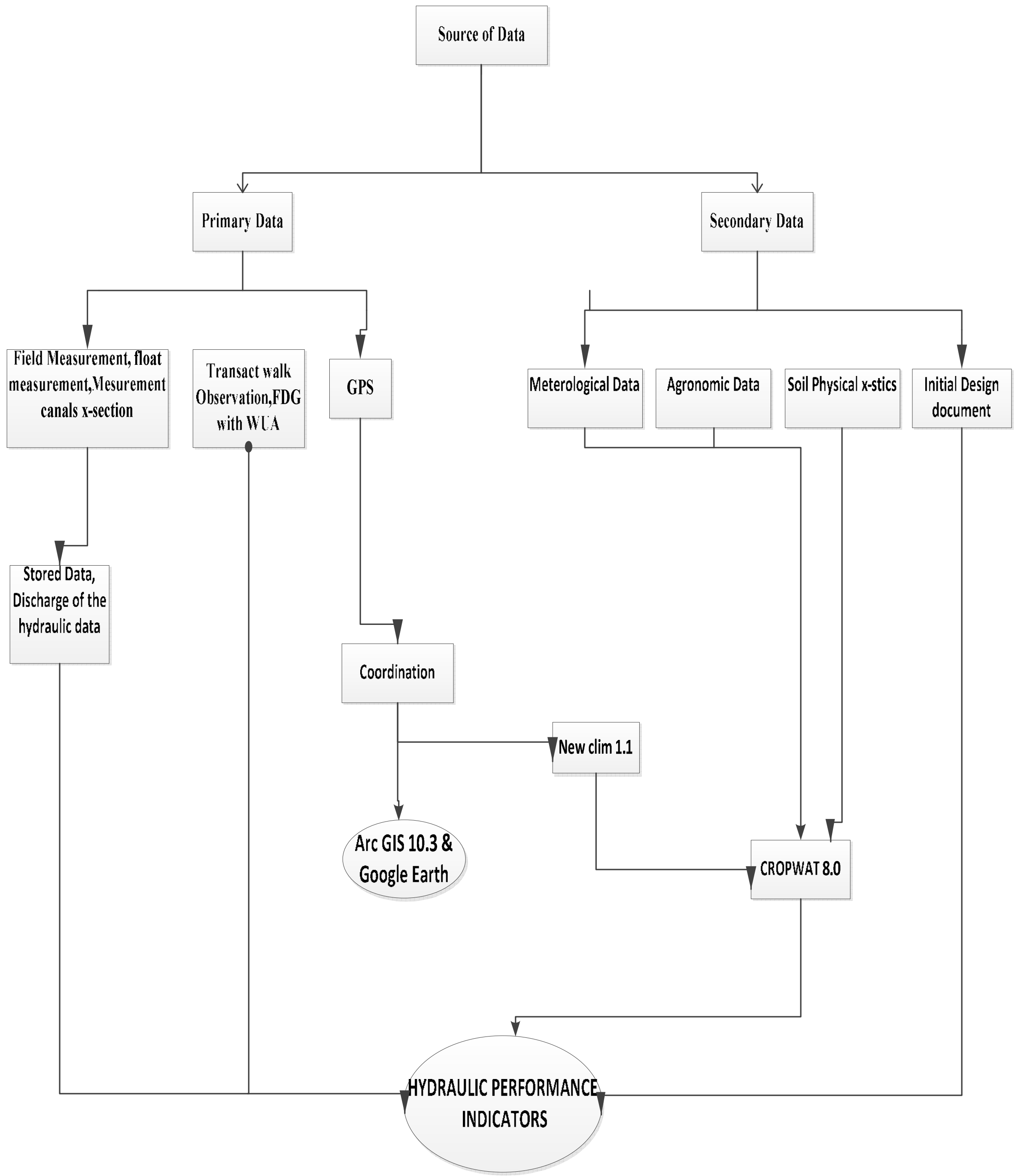


Figure 3.4:Conceptual frame work of the study

4. RESULTS AND DISCUSSIONS

4.1 To analyze the Jidda Irrigation project

These investigations would be undertaken to provide more detailed information on irrigation characteristics on a particular site or several sites, and to provide data for Field considerations of the design requirements and construction methods.

4.1.1 Soil Characterization

The result of laboratory of the soil from the study area is given in table 4.1 below. Based on the Soil samples were taken at soil depth of 0-20 and 20-40cm to investigate the physical propertiesof the soil in the Jidda Irrigation project. The soil texture, Bulk density and moisture content before and after irrigation were analyzed. The soil textural class was determined based on the particle size distribution using USDA SCS Soil textural Triangle Method. The soil particle classification at the head, middle and tail end of the irrigation scheme is given Table 4.1. It may be seen from table 4.1 that the soil textural distribution in the irrigation project was clay in the entire area.

Table 4. 1: Soil Textural Classes of the Irrigation Scheme

Test plot	**Soil Depth, cm**	**Particle size distribution,%**			**Textural class**
		sand	**Clay**	**Silt**	
PLOT 1	0-20	16.42	40.72	42.72	Silt Clay
	20-40	14.43	48	37.57	Clay
PLOT 2	0-20	6.69	60.76	32.55	Clay
	20-40	6.89	66.50	26.61	Clay
PLOT 3	0-20	8.65	58.14	33.21	Clay
	20-40	9.54	44.65	45.81	Clay

The measured values of the soil Bulk density in the irrigation scheme Varied from 1.18 to 1.2g/cm^3 Appendix Table 7.14. The Bulk density values were similar to the values as proposed by Jores *et al*., (2003) and within the range recommended in the literature for specified soil type. This indicates that there was no soil compaction that could limit water infiltration and crop root penetration. The measured value of gravimetric soil moisture content before and after irrigation at different locations evaluated using the oven dry method is given in Appendix 7.8

4.1.2 Design Approach for New Irrigation Project

In irrigation project design, assessment of irrigation requirement was indispensable. In doing so, climate, crop and soil, cropping pattern of that particular area were used as key factors. The study area is now under rain fed agriculture. Existing cropping pattern cannot be representative for irrigation need assessment as irrigation water need assessment conducted assuming that the study area was brought under irrigation. It is not doubtful that introduction of the irrigation will change the cropping pattern of the area. Having this fact as an input, cropping pattern at Jidda irrigation project was taken as representative for the whole study area. Farmer's preference which is rooted in marketing failure, disease resistivity of the crops, cost of pesticides etc. is believed to be the cause for the expected change and for both existing and expected cropping pattern tabulated in Table 4.2.

Table 4. 2: Area coverage of dominant crop at Jidda Irrigation project

Crop Type	Area	ETO(mm/day)	Etc	Eff. Rain	TNI req(mm)	TGI req(mm)	supply req/T
Oion	10	3.34	3.28	175.4	269.7	385.3	3.85
Maize	10	3.34	2.72	315.8	146	208.5	2.08
Cabbage	7	3.34	3.04	519.1	208.5	297.9	2.97
Potato	3	3.34	3.13	314.4	179.5	256.5	2.56
Total	30						

Scheme supply Design: From irrigation land suitability study, 60 ha was found to be suitable for irrigation in the study area.

Availability of Irrigation water

The measured discharge of the river is 30l/sec and the discharge from night storage is 71l/sec. That is the total discharge 101l/sec. The water Duty is 1.7l/s/ha. Thus, the command area to be developed is equal to discharge measured divided by the water Duty. That is command Area=discharge/Duty. Before night storage 57.37 ha irrigation is cultivated and after night storage 37.34 ha.

Therefore, there is enough irrigation water to develop 94.61ha of command area.

4.1.3 Crop Water Requirement and Irrigation schedule

4.1.3.1 Determination of Reference Crop Evapotranspiration(ETo)

The reference Crop Evaporation (ETo) respects the potential evaporation of a well watered grass crop. Based on the procedure described in the Methodology of part, ETo values of the Project were computed. Summary of metrological data and computed value of ETo given in appendix Table 7.11 and the variation of ETo values during different month is shown in Figure below. The maximum and minimum daily ETo values of irrigation project were 3.77mm/day In April and 2.66mm/day In June respectively. The estimated average daily ETo values were 3.17mm/day. As indicated in figure 4.1 the mean monthly ETo values were much higher than that of a mean monthly Effective rainfall during all months. As a result extra irrigation water is required to fulfill the Evapo transpiration demands of the environment. However, to increase water productivity in irrigated agriculture it is needed to select crops which have minimum water demand and select irrigation method which results water losses.

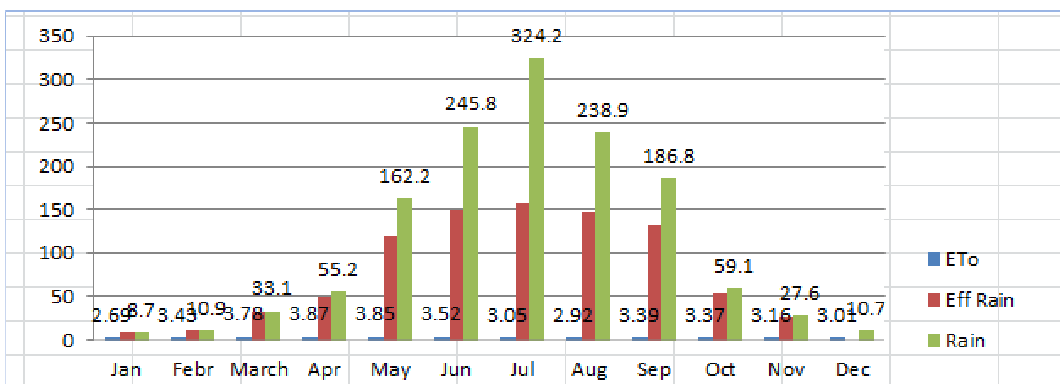


Figure 4.1: Variation of Mean monthly Rain fall, Eff rain fall and ETo

4.1.3.3 Determination of Crop Water Requirement and Irrigation Requierment

CROPWAT 8.0 model needs climatic data, crop characteristics data and soil description for the determination of ETo. crop water requirements and irrigation water requirements .Crop coefficient (Kc), maximum root depth (m), crop height, yield reduction factor (Ky) values were adopted from FAO Irrigation & Drainage paper 24 and 56. The detailed values for different crop growth stage are given in Appendixes Table 7.13, 7.14, 7.16 and 7.17. The Kc values varies during the growing period and are represented by crop coefficient curve. The CROPWAT model required three values of Kc coefficients (Kc during initial, development and late growth stages). The total crop water and irrigation water requirements were computed using above input data for the estimation of total water demands for the irrigation project during the growing season. The overall irrigation efficiency for the small-scale irrigation scheme was assumed equal to 45% Chancellor and Hide, (1997). The calculated seasonal values of crop water requirement (CWR) and irrigation water requirements (IWR) for the entire crop season for the major crops (onion, maize, cabbage and pepper) grown in the study area during the study period are given in Table 4.3

Table 4. 3: Seasonal Crop and Irrigation Water Requirement for Different Crops

Crop	Area,ha	CWR(mm/season	Eff.Rain(mm/season	Irr.Req(mm/season)
Oion	15	318.8	175.4	151.3
Maize	10	369.7	315.8	118.2
Cabbage	7	512.5	519.1	116.1
Potato	13	422.2	314.4	132.1
Total	35			

4.1.4 Components of Head Works

A Head Regulator structure is provided to facilitate the diversion and regulation of water from the river into the main canal. The river water thus diverted into the canal system is utilized to meet the water demand for irrigation as well as for other needs like domestic needs of population settled in and around the command area and or for the needs of livestock in the area. There were one under sluice gates. It was not under utilization of silt excluding and there was no trash-rack designed or implemented. As a result of this there was a deposited of high amount of debris.

Figure 4.2: Diversion weirs Head Regulator

4.1.5 Conveyance Systems and Water Control Structures

i. Main Canal

The man canal is Masonry lined starts from water abstraction site on the right side and conveys water for a length of 1km. The main canal is aligned along contours and supplies to one secondary and five tertiary canals and has a rectangular cross section. The discharge of the main canals varies from time to time along the parent source. The maximum discharge capacity of the main canal of the Jidda irrigation project is 30 liter per second. Despite some breaching of canals by illegal users hydraulically the structure was under good condition. 1.5km length secondary canal leads water from the main canal in to the command area with the maximum discharge capacity 110 meter per second running down slope. Hydraulically the structure was under condition. During field survey breaking of main canals and illegal water abstraction of irrigation water using water pump even out of irrigation scheme was observed. The canal as shown on (photo 4.4) it was covered by weed, sand & silt and is poorly lined with concrete it is also a little part and it started to be damage.

Figure 4. 3: Main canal

4.1.6 Drainage System

A drainage system has a system which prevents ponding of water on the field or controls the water table. Furrow irrigation, the most traditional method of surface irrigation, is recommended for this project, for the following reasons. It is suitable to the soil type of the project area; It has been traditionally exercised by the farmers of the project area; It is easily manageable at farmers level; It is suitable to irrigate all crops, which are recommended for the project. Therefore, the irrigation water management study is one of the focusing areas to evaluate the water managements of Jidda irrigation scheme found in the catchment area whether it has impact on the drastic expansion of the Catchment and to determine the surface outflows drain to sub basin of Abay river. There are also off takes made by farmers but have no gates to control the flow of water. As discussion was made with the users of the scheme, they irrigate their crops at night since there is shortage in day time. Therefore, if the farmers do not use the irrigation water in the off takes day and night, it drains to Abay River.

As shown in figure 4.4, some part of the drainage system is under a threat of collapse because, in most parts, irrigators are not using flow turnout structures constructed because they are either cannot divert the required discharge according to their interest or the structure is filled with silt because lack of maintenance.

Figure 4. 4: Cross drainage structures

4.1.7 Current Status of Irrigation Structures

On the main canal, two drop structures were constructed from which the four were designed. On the same canal, there were thirty three off takes implemented as indicated on first plan. From these structures, six were damaged & others need maintenance. The four cross drainage structures were constructed as per the design document and two of them need maintenance. From the planned five road crossing pipe culverts, only two was constructed because of budget dalliance.

Table 4. 4: Structures constructed on Main canal

Type of structures on the main canal	Designed work In numbers	Constructed in number
Main canal	300m lined 2150m earthern	1km
Catch drain	4	4
Drops structures	4	4
Off-takes	33	33
Road crossing pipe culvert	5	2
Division boxes	2	10
Check structures	8	4
Canal Water escape	1	6
Storage pond (1633m^3)	1	1

4.2. Performance evaluation

The performance of any irrigation system is the degree to which it achieves the desired objectives. Hence, evaluations are useful through a number of tools in order to improve the overall management of the system and enhance efficiency. According to (Molden *et al*., 1998) the principal objective of evaluating the performance of irrigation systems is to identify management practices and systems that should be effectively implemented to improve the irrigation efficiency. Moreover, performance is to be assessed to improve system operations, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess impacts of interventions, to diagnose constraints; to better understand determinants of performance, to compare the performance of a system with others or with the same system overtime.

As many farmers are managing irrigation, scheme does not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement Jorge, (1993).

4.2.1. Technical Performance Evaluation

Technical performance evaluation analysis was conducted using technical efficiencies indicators. The technical evaluations were made for the following indicators; namely, conveyance efficiency, application efficiency, overall scheme irrigation efficiency, and water storage efficiency to evaluate the performance of the project studied.

4.2.1.1 Determination of Conveyance Efficiency

The main canal is 1km long from the water source and only 300m of the canal is lined with masonary. Some secondary and tertiary canals are also unlined (earthen canal). The secondary canals is 1.5km long. The conveyance efficiency of the main canal and Earthen canal monitored during the study at Jidda Irrigation is presented in Table 4.5. The Average conveyance efficiency of the main lined canal was found to be **91.65%,** while the main unlined canals(Earthen canal) is **56.11%.** The lower conveyance efficiency of earthen canals could be due to high infiltration rate of the soil. This also shows there is water loss in the scheme due to excessive percolation.

Table 4. 5: Main canal conveyance efficiency and loss using velocity area method

Canal Taype	Avg Depth (m)	Avg Width (m)	Area (m²)	Length (m)	Time Elapsed (sec)	Velocity (m/sec)	Discharge (m³ /sec)	Conveyance Efficiency (%)
Lined Canal	0.062	0.5	0.031	15	25	0.6	0.0186	**96.77**
	0.057	0.5	0.0285	24	38	0.632	0.018	
	0.53	1.23	0.652	30	25.2	1.19	1.464	87.09
	0.9	1.23	1.107	36	31.26	1.152	1.275	
Average								**91.65**
Earthen Canal	0.12	0.37	0.044	40	76	0.5263	0.02337	**65.29**
	0.1	0.37	0.037	40	97	0.4123	0.01526	
	0.2	0.63	0.123	45	134	0.3358	0.04231	**46.61**
	0.14	0.5	0.07	60	213	0.2817	0.01972	
Average								**56.11**

Figure 4. 5: Upstream and downstream conveyance efficiency measurement

4.2.1.2 Determination of Application Efficiency

The application efficiency found in the Upstream 55%, in the Middle stream 62% and in the Downstream 51% for field of the three plot with average value of **56% (Table 4.7).** The value obtained are still not in the ranges expected of such surface irrigation method that is 60 percent to 75 percent (FAO,1988). Since the area practiced traditional irrigation schemes there was low application efficiency as well as Lack of knowledge of water Application depth and requires skill of Irrigation scheduling. However, according to the conclusion of Solomon (1998) and Keller (1992), the water application efficiency of the command area was below acceptable. The reason for poor water application efficiency may be as small scale irrigation is associated to lack of technical capacity of farmers resulted from absence of extension workers and the required training.

Table 4. 6:Application efficiency for three field location test plots

Field code	**Area(m^2)**	**Total Volume(Lit)**	**Applied Depth (mm)**	**Soil Moisture(mm)**	**Depth stored(mm)**
U/S	253	41104	162	200	90
M/S	409.5	85270	208	200	128
D/S	570	120880	212	200	108

Table 4. 7: Application Efficiency and Storage Efficiency

Field code	**Applied Depth (mm)**	**Stored Depth(mm)**	**Soil Moisture(mm)**	**Application Efficiency, Ea (%)**	**Storage Efficiency, Es (%)**
U/S	162	90	200	55	45
M/S	208	128	200	62	64
D/S	212	108	200	51	54
Aver.				**56**	**54.3**

4.2.1.3. Determination of Storage Efficiency

Storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application. The water storage efficiencies (Er) computed by monitoring soil moisture before and after irrigations. The storage Efficiency for the upstream plot is 45%, for the Middle stream 64% and For the Downstream **54%(Table4.7)** for the location of test plot and the Average result obtained for the Three test plot is **54.3%**. According to Raghuwanshi and Wallender(1998), the recommended storage efficiency is **87.5%.** Thus, the storage efficiency of the scheme indicated that the irrigation system was not adequate in fulfilling the soil moisture required for good productivity of the crop.

4.2.1.4. Overall Scheme Efficiency

The overall efficiency of the scheme is the ratio of water made available to the crop to the amount released at the headwork. In other words, it is the product of conveyance efficiency and application efficiency. In the present study the overall efficiencies of the irrigation schemes at Jidda were found to be **53.4**. The details of overall scheme efficiency of the schemes were derived from the Table 4.1 and 4.2 while the average overall irrigation scheme efficiencies of the schemes are shown in Table 4.4.

The result indicated that the Jidda irrigation scheme was relatively good. The overall efficiency of the Jidda irrigation scheme was within the range of values (50-60%) commonly observed in other similar African irrigation schemes (Sava and Frenken, 2002).

Table 4. 8: Average irrigation efficiencies at Jidda irrigation schemes

Internal Performance Indicators	Jidda Irrigation Efficiencies (%)		
	U/S	**M/S**	**D/S**
Conveyance Efficiency			
-Lined conveyance Efficiency	91.65		
-Unlined conveyance Efficiency	56.11		
Application Efficiency	55	62	51
Storage Efficiency	89	90	91
Distribution uniformity			
Irrigation uniformity			
Over all irrigation Efficiency	**53.4**		

4.2.2. Economic Performance Evaluation

The economic efficiency of the project was evaluated by comparing the benefits gained from the onion yield with the total cost of production. The necessary cost data's for onion production during the study period were collected from the irrigators at the plot level.

4.2.2.1. Water Productivity In Terms Of water Applied (CWP)

From Table 4.9 shows that the Production per unit water applied result obtained were 12.08 kg/m3, 18.14 kg/m3, 20.26 kg/m^3 for upstream, middlestream, downstream location of the test plots respectively. The result indicates that the reduction in yields is because of different cultural practices in the fields. Here, the productivity for the farmer's field located at downstream of the scheme had the highest return per unit of water consumed (**20.26kg/m3**). May be because of good cultural practices of the farmers.

Table 4. 9: Onion Production per unit water applied

Field location	**Field size (ha)**	**Water applied depth (mm)**	**Water applied (m3)**	**Water applied (m^3/ha)**	**Bulb weight (kg)**	**Bulb weight (kg/ha)**	**CPW (kg/m3)**	**EWP (birr/m3)**
U/S	0.0253	1302.4	329.5	13023.7	398	157312.3	12.08	42.3
M/S	0.0409	975.8	399.6	9758.3	725	177045.2	18.14	63.49
D/S	0.0570	319.5	182.1	3194.7	369	64,736.8	20.26	70.91

The analyzed input cost breakdown and the total net benefit per unit of water applied results are tabulated in Tables 4.10

Table 4. 10: Cost of water applied

Field location	**Area (ha)**	**VWA (m^3/season)**	**VWA (m^3/ha/season)**	**Water Cost (birr/1000m^3)**	**TWC (birr/ha/season)**
U/S	0.0253	329.5	13023.7	5	39.5
M/S	0.04095	399.6	9758.3	5	24.5
D/S	0.0570	182.1	3194.7	5	17.5

Note: CWP: is productivity of water in terms of water applied, EWP: estimated water productivity, VWA: Volume of water applied and TWC: Total water cost productivity in terms of monitory units; an average.

4.2.2.2 Total Cost of Birr/ha and Birr/Plot

Table 4.11 indicates that the total cost of Birr/h For Upstream is 29645.8 Birr/ha (750.04Birr/0.0253ha), For Middle stream 32090.8Birr/ha(1314.12 Birr/0.04095ha) and For Downstream 15110.4Birr/ha(861.29 Birr/0.0570ha). The yield of onion under farmers` condition is very low (6 t/ha) and as high as 35t/ ha under good management practice (Getachewet al., 2009). The wide gap in yield is attributed to lack of improved varieties, poor agronomic practices and soil fertility and diseases (bulb rot and downy mildew) and insect pests (onion thrips), etc in farmers` field

(Getachew and Asfaw, 2000). From this study, we can conclude that onion production under this project was economical.

Table 4. 11: Cost break down for Onion production in 2012

Field location	Area (ha)	Cost break down (birr/plot/season)				Total cost (birr/plot)	Cost (birr/ha)
		Potato cost	Pesticide cost	Water cost	Other cost		
U/S	0.0253	385.07	50	0.99	23.18	750.04	29645.8
M/S	0.04095	659.62	90	1.20	37.52	1314.12	32090.8
D/S	0.0570	448.62	60	0.55	26.87	861.29	15110.4

Remark: Labor cost includes costs for land preparation, planting, weeding, harvesting (uprooting), fertilizering and transporting etc. The present value of benefits and costs were determined by taking current interest rate 5% and since a project had long life age, the economic efficiency was predicted for 10 years of life.

Table 4. 12: Net present worth (NPW)

Field location	Area (ha)	Yield (kg/ha)	Average market price (birr/kg)	Gross benefit (birr/ha)	Total cost (birr/ha)	Net benefit (birr/ha)	$(1+r)^t$ $=(1+0.5)^{10}$	NPW (birr)
U/S	0.0253	15731.2	20	314624	29655.8	284968.2	1.04	274007
M/S	0.04095	17704.0	20	354080	32100.0	321980	1.04	309596
D/S	0.0570	6473.7	20	129474	15120.4	114353.6	1.04	109955

Note: An average market price of onion is 20.0 birr/kg.

4.2.2.3. The Benefit Cost Ratio

The benefit cost ratio was computed using equation given on 3.13 and 3.14 and the result was presented on the Table 4.8. the benefit-cost ratio results observed for the three location users were: For upstream users 6.36, For middle Stream users 6.62 and for the down Stream users 5.14. The maximum economic efficiency was found in middle location irrigators (6.62) where as the minimum economic efficiency was found in tail location beneficiary (5.24) next to upstream irrigators (6.36). This might be due to farmers in the middle fields applied water nearly equal to the water requirement of the crop as calculated by CROPWAT software program.

In general, the analysis indicates that onion production in the scheme is economically efficient in terms of water use, since the benefit-cost ratio values of the three locations were more than one. If the ratio of benefit to cost is greater than one, the technology is considered feasible for Adoption.

Table 4. 13: Economic efficiency

Field location	Gross benefit (birr/ha)	Total cost (birr/ha)	Net benefit (birr/ha)	$(1+r)^t$	PV of benefits (birr)	PV of costs (birr)	B/C ratio
U/S	314624	29655.8	284968.2	1.04	302523	28515	10.6
M/S	354080	32100.0	321980	1.04	340461.5	30866	11.03
D/S	129474	15120.4	114353.6	1.04	124494.2	14539	8.56

5. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

This study is not forwarding the most detail evaluation and characterization for this project because, the project is very huge, far from public transport access and tedious to go through when compared with the weather condition it has. But, it can be an encouragement for further studies for the sustainability and increasing efficiency of this project. From this study, the following conclusions can be outlined.

i. The most problem of this project was not only timely completion but also frequent revision of design and shortage of budget that made the project under performance.
ii. One under sluice gates was not functional. Additionally, it was not opened timely for silt exclusion service.
iii. Most of the structures found on main canal are in need of maintenance and some are completely damaged
iv. Silting up was a serious problem of weir site and main and branch canals because of not proper functioning of the under sluice gate.
v. Farmers were creating their own conveyance system by passing developed canal turn outs and water control structures that were necessary but not done during the construction time. Consequently, there was tremendous water loss when water was made to flow on temporary conveyance system.
vi. The system permitted farmers to apply large volume of water to their fields combined with poor knowledge about the crop water requirements of the farmers.
vii. On the design document, integrated water shade management plans; both engineering measures and bio measures were recommended. However, on the field visit, no water shade management work was implemented whether to protect the main canal or to protect flood coming in the canal with canal silting materials.

It can be concluded that productivity of the cropping system can be improved by minimizing water losses due to deep percolation losses and over- irrigation of the root zone and applying water according to water requirement.

5.2. RECOMMENDATION

From the study, the following recommendations are forwarded from performance evaluation studies of the Jidda Irrigation project.

i. The under sluice gates must be opened when there is enough flow to flash out the deposited silt.
ii. There should be trash rack on the inlet which prevents debris from entering conveyance system or blocking the inlet.
iii. Timely design and construction of irrigation structures contributes for equity of water distribution among farmers at different locations and for achieving the most plan of production.
iv. Any organization, which belongs, should give attention on guidance and support of farmers in developing and introduction of appropriate depth of irrigation, irrigation interval, in addition to improving physical infrastructure of the scheme (on aqueduct, dykes and other structures maintenance and construction) for future use.
v. The efficiency of the project needs improvement, therefore the following measures can be taken:
vi. Regular maintenance of cracks, holes, furrows, damages and leaks in water control structures is simple and effective to improve irrigation efficiency
vii. Control of weed growth in the unlined canals, waterways and field channels can improve canal conveyance efficiency
viii. Farmers may provide training on water management and irrigation practices to avoid any undesirable impacts of irrigation such as water logging and salt accumulation.
ix. Introducing high value crops, agricultural intensification, increasing land and water productivity through integrated management and increasing irrigation intensities are very relevant to increase the output value of production per unit irrigated area and command area in Indris irrigation project.

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7. APPENDICES

7.1. ADDITIONAL TABLES AND PHOTOS

Appendix Table 7.1:Monthly Rainfall in (mm) Station-SHAMBU

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1999	29.2	0	0.5	36.2	219.8	303.5	189.3	250.2	241.2	256	2.5	0	1528.4
2000	6.3	0	3.3	115.2	146.8	228.4	294.9	279.7	195.4	0	36.1	36.2	1342.3
2001	0	12	106.6	54.6	217.1	175.2	324.2	198	145.1	77.4	31.1	9.5	1350.8
2002	11.9	13.5	97.9	57.2	107	243.1	544.7	361.2	197.7	23.8	4.5	23.9	1686.4
2003	6.5	33.4	67.2	7.4	1.4	351	248.3	238.1	326.4	3.8	35.1	30.7	1349.3
2004	12.2	5.4	18	96.9	126.8	271.4	314.9	229.4	241.7	134.8	19.8	18	1489.3
2005	12.9	3	0	58.3	96.4	279.9	316	315.6	222.4	59.3	21.1	0	1384.9
2006	0.5	50.2	52.7	21.1	198.3	305.3	328.7	187.2	335.9	98.8	11.5	29.6	1619.8
2007	14.9	80.9	25.4	98.2	205	246.4	358.6	281.1	257.7	88.4	0	0	1656.6
2008	0.5	2	0	81.7	293.1	259.9	379.3	344.9	191.2	0	92.8	10.3	1655.7
2009	13	17.1	55.1	95.5	17	229.4	339.9	0	126.1	179.3	22.7	11	1106.1
2010	29.1	2.2	29	80.3	290.6	185.6	299.3	289.4	189.4	12.6	10.4	13.8	1431.7
2011	5.9	1.2	45.9	23.5	229	197	362.9	210.6	292.1	7.3	44.6	1.9	1421.9
2012	25.5	0	93.2	9.7	113.2	271.5	397.4	324.3	248.4	37.7	15.8	4.1	1540.8
2013	2.5	1.2	12.8	29	270.9	291.9	369.5	222.5	188.2	85.1	69.8	0	1543.4
2014	11.5	0	50.6	157	314.2	205.9	217.1	363.1	226	85.8	85.5	21.2	1737.9
2015	0.3	7.4	17.6	11.6	0	203.7	325.4	347.1	200.4	21.3	40.7	15.8	1191.3
2016	0	0	0	0	354.8	0	315	0	0	0	0	0	669.8
2017	0	0	19.3	125.9	204.9	273.5	289.2	340.3	0	0	37	0	1290.1
2018	0	0	0	0	0	298.2	302.4	235.5	99.2	69.3	0	0	1004.6
2019	0	0	0	0	0	340.7	291.9	0	0	0	0	0	632.6
Mean	**8.7**	**10.93**	**33.1**	**55.2**	**162.2**	**245.8**	**324.23**	**238.96**	**186.88**	**59.08**	**27.67**	**10.762**	

Appendix Table 7.2 : Monthly Maximum Temperature in (^oC)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000	23.2	25.6	25.8	25.7	23.4	22	18.7	19.6	21	20.5	22	22.9	247.5
2001	23.7	24.9	26.3	24.4	23.6	21.6	19.8	19.5	20.9	20.2	22	22.9	249.6
2002	23.4	25.1	23.6	24.8	24	20.7	19.8	19.4	21.4	21.7	22.4	23.3	269.6
2003	23.3	25.4	25	25.2	25.7	21.8	21.2	20.2	21.2	22.7	23.7	23.7	279.1
2004	24.5	25.6	25	25.7	27.6	21.9	19.4	19.9	20.6	22.1	23.2	23.6	279.1
2005	24.9	25.4	25.7	24.9	25.4	20.6	20	20.4	21.1	21.5	23.5	23.9	277.3
2006	24.1	27	24.9	25	24.3	22.1	19.3	20.3	21.2	21.7	22.7	24	251.7
2007	25.2	25.8	25.5	25.4	23.7	22.1	20.3	19.5	20.7	22.4	23.2	23.3	277.1
2008	24.2	24.8	26	24.9	23.8	21.3	19.6	19.9	20.8	22.2	23.9	24.4	275.8
2009	25.3	25.8	27	24.8	23	21.8	20.2	20.3	21.9	24.03	21.7	20.1	210.1
2010	24.3	26.1	24.4	26.9	24.1	22.2	19.6	19.7	21.1	22.7	23.3	23	151.6
2011	23.7	26.3	25	26.4	24.2	21.8	20.6	20	21.1	22.7	22.6	24.3	254.4
2012	24.2	26.25	25.5	26.5	24.1	21.3	19.4	19.6	20.8	22	23	23.6	199.3
2013	24.7	26.2	26.2	26.8	23.8	21.4	19.5	19	21.2	21.5	22.7	22.9	275.9
2014	23.9	24.7	25.2	24.7	22.8	22.5	20.2	19.7	20.8	21.5	22.6	22.4	271
2015	23.7	26.1	27.4	26	23.4	22.3	21.5	20.9	21.7	22.8	23	23.2	258.6
2016	24.7	25.9	26.6	25.6	23.2	22.7	20.5	21.9	21.5	20.9	22.6	23.5	68.4
2017	25	25.9	26.4	25.5	23.1	23	20.7	20.1	20.3	20.6	22.5	23.6	209.9
2018	25.3	25.9	27.4	26	23.6	21.6	20.5	20.4	22.2	22.9	23.3	24.2	131.8
2019	25.5	25.9	26.6	25.6	23.2	22.7	21.1	19.5	16.5	16	20.9	22.4	69.3
Mean	**23.13**	**24.42**	**24.53**	**24.2**	**24**	**21.87**	**20.1**	**19.99**	**20.9**	**21.63**	**22.74**	**23.26**	

Appendix Table 7.3: Monthly Minimum Temperature in ^{O}C

Shambu Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000	10.8	12.5	12.8	13.7	12.1	11.4	10.6	10.9	11.1	10.8	10.4	10.4	116.7
2001	10.8	11.6	12.9	12.1	12.5	11.4	10.9	10.9	11.1	10.8	10.4	10.4	125
2002	10.5	12.1	12.4	12.9	12.7	11.5	11.5	11.8	11.4	11.5	10.6	11	139.9
2003	11.3	12.7	12.7	13.2	14	11.9	11.5	11.5	11.5	11.1	11.1	11.5	144
2004	11.8	12.9	13.1	13.6	15.2	11.9	11.6	11.8	11.2	10.8	10.6	10.3	144.8
2005	11.8	11.8	13.3	13.2	13.1	11.7	10.9	11.3	10.9	10	10.4	10.8	139.2
2006	10.9	13.1	12.7	14	13.2	12	11.5	11.5	11.5	10.9	10	9.9	128.5
2007	11.7	12.7	12.9	13.4	12.3	11.4	11.8	11.4	11.3	11.4	11	10.8	142.1
2008	11.4	12.3	12.9	12.7	12.7	11.7	11.4	10.8	11.2	10.4	10.3	9.8	137.6
2009	10.8	11.5	13.7	12.6	11.7	11.3	10.7	10.8	10.8	12.8	12.5	11	103.9
2010	10.7	11.5	13.9	12.5	11.6	11.2	10.9	11.5	11.1	11	10.3	10.5	76.5
2011	10.6	11.5	12.3	13.1	12.2	11.7	11.3	11.2	11.1	9.9	10.3	10.2	125.2
2012	11	11.9	13.1	13.5	14	12.1	11.6	11.6	12.1	11.2	11.6	11.2	133.9
2013	12.4	13.3	14.5	14.7	12.8	11.9	11.3	11.7	11.7	11.5	11.2	10.3	147.3
2014	11.9	12	12.8	12.5	12.5	12.6	12.1	11.1	11.3	11.3	11.2	10.7	142
2015	10.8	13.2	14.8	14.3	12.7	12.6	11.9	11.4	11.3	11.3	11.6	11.7	134.9
2016	12.3	15.4	13.7	13.4	12.9	12.5	12	11.6	11.3	11.3	10.2	9.6	46.8
2017	10.2	12.3	13.7	13.4	12.9	12.5	12.1	11.9	10.9	10.4	10.5	10	119.5
2018	10.2	12.3	13.7	13.4	12.9	11.9	11.5	11.8	11	11.1	10.3	10.8	68.1
2019	9.8	12.3	13.7	13.4	12.9	12.4	12.1	11.9	10.9	10.4	10.5	10	34.3
Mean	**11.08**	**12.45**	**13.28**	**13.28**	**12.85**	**11.88**	**11.46**	**11.4**	**11.24**	**10.99**	**10.75**	**10.5**	

Appendix Table 7.4: Monthly Sunshine duration in (hrs)

Shambu station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2006	9.2	8.8	7.2	6.6	7.3	6.9	3.7	2.9	5.7	7.9	8.1	8.2	82.5
2007	7.5	7.8	8.7	7.1	7.6	5.1	2.3	3.8	5.2	9.5	9.7	9.6	83.9
2008	7.7	7.3	8.1	7.5	7.5	6.8	4.8	3.6	7.4	7.9	7.6	7.7	83.9
2009	8.2	8.1	8.4	8.6	8.6	7.8	2.6	4.1	7	7.4	9.3	7.3	87.4
2010	8.1	5.9	6.7	6.6	6	5.7	2.8	2.6	5.5	8.8	7.1	7.1	72.9
2011	7.2	9.5	6.8	8	7	5.9	4	3.7	5.6	9.2	7.6	8.8	83.3
2012	9.4	9.8	7.7	7.4	8	5.2	3.4	3.5	5.1	9.4	8.5	8.9	86.3
2013	8.2	7.2	6.8	8.8	6.7	5.2	3.1	3	6.5	7.5	8.2	8.9	80.1
2014	7.4	8.3	8.3	8.2	8	7.3	3.6	3	6.4	7.4	8.3	2	78.2
2015	1.2	1.2	1.2	1.3	3.3	2.5	3.5	1.6	3.5	7.1	7.7	1	35.1
2016	1	1.5	1.7	2.2	1.1	2.3	3.1	2.5	3.3	6.5	7.3	5.5	38
2017	4.3	3.4	5.6	6.8	7	5.3	3	2.6	5.8	6.9	8.9	8.4	68
2018	7.5	7.9	5.6	7.2	7.4	5.2	3.1	3.5	7.8	7.8		9.1	72.1
2019	10	9.7	8.2	8.2	8.7	5.8	3.7	4	7.1	7.4	9.5	9.7	92
Mean	**6.921**	**6.886**	**6.5**	**6.75**	**6.729**	**5.5**	**3.336**	**3.171**	**5.85**	**7.907**	**7.7**	**7.3**	**74.55**

Appendix Table 7.5: Relative Humidity in percent (%)

Shambu station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000	419	337	357	511	563	629	653	630	567	0	554	496	7716
2001	438	433	491	487	557	647	681	691	643	607	556	533	8765
2002	546	445	494	500	477	618	654	684	648	547	493	500	8608
2003	440	481	506	439	384	607	678	674	672	544	516	465	8409
2004	457	435	463	506	513	648	673	681	651	583	538	496	8648
2005	441	390	0	473	489	659	686	672	662	582	504	426	7989
2006	444	426	440	442	552	614	672	685	649	601	566	554	8651
2007	503	452	390	491	552	649	693	686	656	526	485	447	8537
2010	0	0	0	0	0	626	645	664	639	530	521	487	6122
2011	484	0	438	423	0	0	0	0	0	518	561	0	4435
2012	0	185	410	394	469	630	685	684	648	507	539	453	7616
2013	388	406	371	337	539	632	671	668	617	584	560	461	8247
2014	436	395	458	517	585	598	667	669	646	571	517	492	8565
2015	414	381	389	384	0	603	79	647	618	544	535	534	7143
2016	0	0	0	0	590	0	662	0	0	0	0	424	3692
2017	302	455	408	468	582	592	657	671	0	0	516	444	7112
2018	0	0	0	0	0	0	0	0	613	570	0	529	3730
2019	390	0	0	0	0	647	664	0	0	0	0	0	3720
Mean	**339**	**290.1**	**311.9**	**354**	**380.7**	**522.2**	**562.2**	**522.6**	**496.1**	**434.1**	**442.3**	**430.1**	**127705**
%	**26**	**22**	**24**	**27**	**29**	**40**	**44**	**40**	**38**	**33**	**34**	**33**	

Appendix Table 7.6: Mean monthly climatic parameters

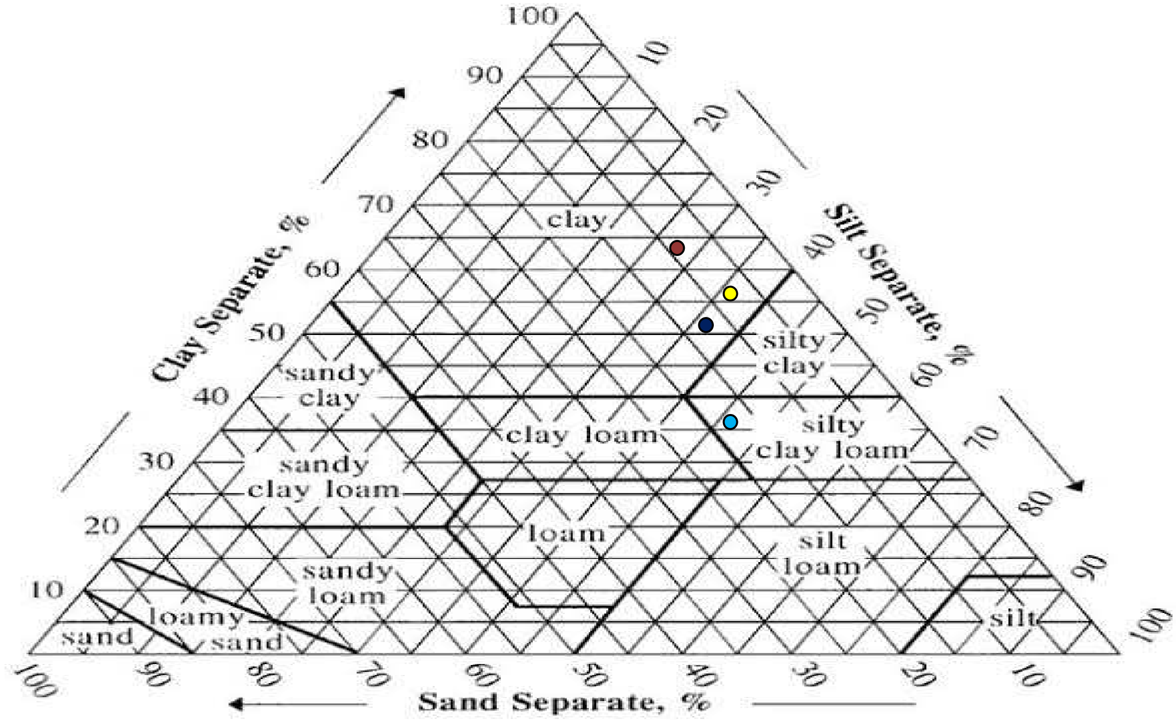
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
SHAMBU													
Rainfall(mm)	8.7	10.9	33.1	55.2	162.2	245.8	324.2	238.9	186.8	59.1	27.6	10.7	1363.2
Max.Temp(C^0)	23.13	24.42	24.53	24.2	24	21.87	20.1	19.9	20.9	21.6	22.7	23.3	22.55
Min.Temp	11.08	12.45	13.28	13.28	12.85	11.88	11.46	11.4	11.24	10.99	10.75	10.5	11.76
Sunshine(hr)	6.92	6.88	6.5	6.75	6.72	5.5	3.34	3.17	5.85	7.91	7.7	7.3	6.21
Humidity (%)	26	22	24	27	29	40	44	40	38	33	34	33	
Wind speed(m/s)	0.9	0.9	1.1	1.1	1.2	1.1	0.9	0.8	0.9	0.8	0.8	0.9	

Appendix Table 7.7: potential and actual average yield of the project

No	Types of crop	Actual average yield per hectare	Potential average yield per hectare
1	Maize	20.00	50.00
2	Potato	95.00	160.00
3	Tomato	60.00	240.00
4	Onion	20.00	90.00
5	Pepper	7.00	12.00

Source: District of agriculture for actual average yield and guide line irrigation agronomy of SSIP, ESRDF and OIDA guide line for feasibility study.

Appendix Table 7.8: Appendix Determination of Soil Texture



Appendix Table 7.9: Period of growing stages of the proposed crops

SN	Crop type	Length of growing stages in days				
		Initial	Development	Mid stage	Late	Total
1	Maize	30	40	50	30	150
2	Onion	25	30	50	15	120
3	Potato	25	30	40	20	115
4	Tomato	30	40	45	25	135
5	H/Cabbage	20	25	60	15	120

Appendix Table 7.10: Crop coefficient of the proposed crops (kc)

SN	Type of crops	Crop coefficient in growing stages			
		Initial	**Development**	**Mid stage**	**Late stage**
1	Maize	0.50	0.90	1.2	0.95
2	Onion	0.60	0.80	1.1	0.90
3	Potato	0.40	0.79	1.2	0.95
4	Tomato	0.48	0.75	1.25	0.85
4	Cabbage	0.45	0.70	1.0	0.97

Source: Guide line on irrigation Agronomy Manual Revised version by Ministry of Agriculture Sept. 2011 Addis Ababa, Ethiopia (page 218)

Appendix Table 7.11: Appendix Average 20 years(1999-2019) Climatic data at Jimma Geneti Station and ETo

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\jida....

Country ETHIOPIA Station HARETO

Altitude 2247 m. Latitude 9.21 °N Longitude 37.28 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	9.0	19.6	9	10	9.8	21.8	2.69
February	9.4	17.1	22	78	6.8	18.8	3.43
March	9.4	18.3	24	95	6.5	19.3	3.78
April	10.2	18.1	27	95	6.7	19.8	3.87
May	9.8	18.3	29	104	6.7	19.4	3.85
June	10.7	19.7	40	95	5.5	17.2	3.52
July	10.9	19.1	44	78	3.3	14.1	3.05
August	9.8	17.0	40	69	3.1	14.1	2.92
September	9.1	17.1	38	78	5.8	18.2	3.39
October	7.8	15.7	33	69	7.9	20.6	3.37
November	7.6	17.4	34	69	7.7	19.1	3.16
December	8.1	16.7	33	78	7.3	17.9	3.01
Average	**9.3**	**17.8**	**31**	**77**	**6.4**	**18.4**	**3.34**

Appendix Table 7.12: Mean Monthly Rain fall and Effective Rain fall(USDA-SCS Method)

Monthly rain - C:\ProgramData\CROPWAT\data\rain\jida.CRM

Station: HARETO   Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	8.7	8.6
February	10.9	10.7
March	33.1	31.3
April	55.2	50.3
May	162.2	120.1
June	245.8	149.1
July	324.2	157.4
August	238.9	147.6
September	186.8	131.0
October	59.1	53.5
November	27.6	26.4
December	10.7	10.5
Total	**1363.2**	**896.6**

Appendix Table 7.13: Relation of soil type and soil moisture contents

Soil Type	**FC**	**PWP**	**Available water per unit depth of soil, mm/m**
Fine sand	3-5	1-3	20-40
Sandy loam	5-15	3-8	40-110
Silt loam	12-18	6-10	60-130
Clay loam	15-30	7-16	100-180
Clay	25-40	12-20	160-300

Appendix Table 7.14: CROPWAT8 Out put of Onion Water Requirement

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Feb	2	Init	0.7	2.4	7.2	0.8	7.2
Feb	3	Init	0.7	2.48	19.8	5.3	14.5
Mar	1	Deve	0.7	2.57	25.7	8.2	17.5
Mar	2	Deve	0.77	2.89	28.9	10.5	18.4
Mar	3	Deve	0.87	3.32	36.5	12.6	23.9
Apr	1	Mid	0.98	3.74	37.4	13.1	24.4
Apr	2	Mid	1	3.88	38.8	14.4	24.5
Apr	3	Mid	1	3.88	38.8	22.9	15.8
May	1	Late	1	3.86	38.6	33.5	5.1
May	2	Late	0.96	3.68	36.8	41.9	0
May	3	Late	0.92	3.42	10.3	12.1	0
					318.8	**175.4**	**151.3**

Appendix Table 7.15: CROPWAT8 Out put of Cabbage Water Requirement

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Feb	2	Init	0.7	2.4	7.2	0.8	7.2
Feb	3	Init	0.7	2.48	19.8	5.3	14.5
Mar	1	Init	0.7	2.56	25.6	8.2	17.4
Mar	2	Init	0.7	2.64	26.4	10.5	15.9
Mar	3	Deve	0.7	2.67	29.4	12.6	16.8
Apr	1	Deve	0.74	2.83	28.3	13.1	15.3
Apr	2	Deve	0.79	3.05	30.5	14.4	16.1
Apr	3	Deve	0.84	3.24	32.4	22.9	9.5
May	1	Deve	0.89	3.43	34.3	33.5	0.7
May	2	Deve	0.94	3.61	36.1	41.9	0
May	3	Mid	0.99	3.7	40.7	44.5	0
Jun	1	Mid	1	3.64	36.4	47.1	0
Jun	2	Mid	1	3.53	35.3	50.7	0
Jun	3	Mid	1	3.37	33.7	51.3	0
Jul	1	Mid	1	3.22	32.2	52.1	0
Jul	2	Late	1	3.04	30.4	53.3	0
Jul	3	Late	0.94	2.82	31	51.9	0
Aug	1	Late	0.89	2.65	2.6	5	2.6
					512.5	519.1	116.1

Appendix Table 7.16: Average soil moisture content before and after irrigation at 40 cm depth

Test plot	Soil depth (cm)	Time of sampling	% of average soil moisture content (wt basis)	Moisture difference	Bulk density (gm/cm3)	% of soil moisture content (vol. basis)	Moisture content (mm)	Stored Depth
Plot 1	0-20	before irrigation	27.37	20.79	1.18	24.53	73.60	**90.41**
		after irrigation	48.16					
	20-40	before irrigation	24.21	4.67	1.2	5.60	16.81	
		after irrigation	28.88					
Plot 2	0-20	before irrigation	37.66	29.47	1.18	34.77	104.32	**128.28**
		after irrigation	67.13					
	20-40	before irrigation	34.04	7.13	1.12	7.99	23.96	
		after irrigation	41.17					
Plot 3	0-20	before irrigation	29.86	21.46	1.18	25.32	75.97	**108.08**
		after irrigation	51.32					
	20-40	before irrigation	24.02	8.92	1.2	10.70	32.11	
		after irrigation	32.94					

Appendix Table 7.17: Irrigation water measurement result (Jidda irrigation scheme)

Field code	Area(m^2)	Time(Sec)	Discharge(L/S)	T. Volume	Applied depth(mm)
U/S	253	8055	5.1	41104	162
M/S	409.5	11369	7.5	85270	208
D/S	570	11680	10.3	120880	212

Appendix Table 7.18: CROPWAT8 Output of Potato Water Requirement

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Feb	2	Init	0.5	1.71	5.1	0.8	5.1
Feb	3	Init	0.5	1.77	14.2	5.3	8.9
Mar	1	Init	0.5	1.83	18.3	8.2	10.1
Mar	2	Deve	0.54	2.05	20.5	10.5	10
Mar	3	Deve	0.74	2.81	30.9	12.6	18.3
Apr	1	Deve	0.95	3.64	36.4	13.1	23.3
Apr	2	Mid	1.09	4.22	42.2	14.4	27.8
Apr	3	Mid	1.1	4.23	42.3	22.9	19.4
May	1	Mid	1.1	4.22	42.2	33.5	8.7
May	2	Mid	1.1	4.21	42.1	41.9	0.2
May	3	Late	1.09	4.07	44.8	44.5	0.2
Jun	1	Late	0.98	3.57	35.7	47.1	0
Jun	2	Late	0.85	3	30	50.7	0
Jun	3	Late	0.74	2.49	17.4	35.9	0
					422.2	**341.4**	**132.1**

Appendix Table 7.19: CROPWAT8 Output of Maize Water Requirement

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Feb	2	Init	0.3	1.03	3.1	0.8	3.1
Feb	3	Init	0.3	1.06	8.5	5.3	3.2
Mar	1	Deve	0.3	1.11	11.1	8.2	2.9
Mar	2	Deve	0.45	1.71	17.1	10.5	6.6
Mar	3	Deve	0.7	2.66	29.3	12.6	16.7
Apr	1	Deve	0.95	3.63	36.3	13.1	23.2
Apr	2	Mid	1.12	4.31	43.1	14.4	28.8
Apr	3	Mid	1.12	4.33	43.3	22.9	20.4
May	1	Mid	1.12	4.32	43.2	33.5	9.7
May	2	Mid	1.12	4.31	43.1	41.9	1.2
May	3	Late	1.04	3.88	42.7	44.5	0
Jun	1	Late	0.77	2.81	28.1	47.1	0
Jun	2	Late	0.52	1.82	18.2	50.7	0
Jun	3	Late	0.36	1.22	2.4	10.3	2.4
					369.7	**315.8**	**118.2**

Appendix Table 7.20: Photo of Soil sample taken from the Irrigation sight