PERFORMANCE EVALUATION OF SMALL SCALE IRRIGATION SCHEMES - THE CASE OF ELLA AND BOSSA SCHEMES IN HUMBO WOREDA, SNNPRS, ETHIOPIA

M.SC. THESIS

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN WATER RESOURCE ENGINEERING AND MANAGEMENT

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE DEPARTMENT OF WATER RESOURCE AND IRRIGATION ENGINEERING INSTITUTE OF TECHNOLOGY SCHOOL OF GRADUATE STUDIES HAWASSA UNIVERSITY HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN WATER RESOURCE ENGINEERING AND MANAGEMENT

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This is to certify that the thesis entitled "PERFORMANCE EVALUATION OF SMALL SCALE IRRIGATION SCHEMES - THE CASE OF ELLA AND BOSSA SCHEMES IN HUMBO WOREDA, SNNPRS, ETHIOPIA" submitted in partial fulfillment of the requirements for the degree of master's with specialization in water resource engineering and management, the graduate program of the department of water resource and irrigation engineering, and has been carried out by Tinsae Dalga, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by Tinsae Dalga have read and evaluated his thesis entitled "PERFORMANCE EVALUATION OF SMALL SCALE IRRIGATION SCHEMES - THE CASE OF ELLA AND BOSSA SCHEMES IN HUMBO WOREDA, SNNPRS, ETHIOPIA", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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I, the undersigned person, declare that this thesis is my work and that all sources of materials used for the thesis have been duly acknowledged.

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Place: Hawassa University Institute of Technology

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ACRONYM

ADLI	Agricultural Development Lead Industrialization
ARIS	Annual Relative Irrigation Supply
ARWS	Annual Relative Water Supply
BTA	Beneficiaries of Targeted Area
CBIWM	Community based Irrigation Water Management
DA	Development Agent
Ec	Conveyance efficiency
EIA	Environmental Impact Assessment
FAO	Food and Agricultural Organization of the Nations
FDRE	Federal Democratic Republic of Ethiopia
FTG	Farmer Training Group
FHH	Farmer Households
GDP	Grows Domestic Production
GPS	Global Positioning Systems
GTP	Growth and Transformation Plan
IFAD	International fund for Agricultural Development
ICID	International Commission in Irrigation and Drainage
IWMI	International Water Management Institute
LSC	Lower secondary canal
m.a.s.l	Meter Above Sea Level
MLMC	Middle lined main canal
MSC	Middle secondary canal
MoWR	Ministry of Water Resource
NCWR	Net crop Water Requirement
NIR	Net Irrigation Requirement
ODA	Overseas Development Administration
OM	Operation and Maintenance
PASIDP	Participatory Small- scale Irrigation Development Programme
RIA	Relative irrigated Area
SNNPRS	South Nation Nationalities People Regional State

SSA	Sub-Saharan-Africa
SSI	Small Scale Irrigation
ULMC	Upper lined main canal
UUSC1	Upper unlined secondary canal
WUA	Water User Associations
WWMEO	Woreda Water Mine and Energy Office

ABSTRACT

Small-scale irrigation is one of the important pillars of the food security strategy of Ethiopian government that designed to promote the food production of small holder farmers. This study was aimed to investigate the performance of the Ella and Bossa small-scale irrigation schemes. To meet the objective, the primary and secondary data were collected. The primary data were collected through household interviews, focus group discussions, key informant interviews and field observation to identify problems of the existing schemes, and discharge measurement was done at different main and secondary canal sections. The water delivery performance indicators such as conveyance efficiency, relative water supply, and relative irrigation supply, the selected sustainability, agricultural and financial indicators were used to estimate and compare the performance of the schemes. The secondary data were collected from office of water resource and irrigation, office of agricultural and natural resource and different published materials. Conveyance efficiency result for both Ella and Bossa schemes was found to be 76.25% and 75.54%, Relative water supply was found as 1.10 and 0.96, it shows that in Ella scheme there is excess water amount diverted from the river Likewise, in Bossa scheme the value is not shows there is water shortage but, for deficit irrigation system it is optimum amount of water to meet the crop water demand, relative irrigation supply was found to be 1.15 and 0.90, this value indicates that in Ella scheme there was over supply of water and in the case of Bossa scheme, the value indicates that there was water shortage delivered as compared to irrigation needed respectively. From selected physical performance indicators, the result of RIA found to be 74% and 75.6%, BTP 78.6% and 70%, and SIA 108.2% and 172%, from agricultural indicators, OPUIA was found to be 32310.81 and 30961.03birr/ha, OPUCA 23910 and 23392.78birr/ha, OPUWIS 8.46birr/m3 and 11.60birr/m3, and OPUWC 5.18birr/m3 and 5.26birr/m3, and from the financial indicator GIR was obtained to be 37.2% and 33.5% for Ella and Bossa schemes respectively. From the interviewed farmers the main canal siltation, sedimentation, upstream flooding, downstream scouring, and damage on farmland canals were the utmost stirring physical problems in each scheme. Lack of credit, lack of supply of improved seeds, weakness of WUA, market problem and lack of community participation on construction were the key socio economic problems identified in both schemes. Based on the findings frequent performance assessment of the schemes, capacity building of professionals and irrigators, the design of any small scale irrigation project should consider different aspects of social, cultural and economic aspects of the beneficiaries and implementation of water shade management practices on the upper catchment were the policy recommendations to alleviate the problems identified and improve the performance of the schemes.

Key words: - *Small scale irrigation schemes, performance indicators, and current status of SSI*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Agriculture covers for about 70 percent of the economically active population in Sub-Saharan Africa, and it remains a significant social and economic sector. In SSA including Ethiopia, rain-fed agriculture is mostly dominated the sector: Food security and income of rural populations are affected by rainfall variability, and food production is often less than the requirements of a growing population. The volatile rains and soil degradation partly explain the stagnation of agricultural yields, one cause of the chronic food deficit (FAO, 2006).

Irrigation can increase and ensure agricultural production significantly and it is unquestionably one option for development. However, irrigation investments must be carefully planned. Water is indeed a limited resource and sharing it between its multiple users' calls for integrated forms of management. In addition, irrigated agriculture requires relatively high investments in term of financial and human resources. Consequently, irrigation productivity and sustainability must be assessed with care. The success of irrigation projects generally depends on the involvement of the concerned communities and comprehensive analysis of the technical, economic, social and environmental factors (FAO, 2006).

Ethiopia is one of the Sub Saharan Africa countries characterized by a low standard of living and widespread poverty. Agriculture is the main stay of the rural population and the sector plays a vital role in the national economy. The sector contributes almost 41% of the gross domestic product (GDP); 90% of the foreign exchange earnings and employs, almost 85% of the total population living in the rural and agricultural sector (FDRE, 2010). Ethiopia is still following the predominantly agricultural economy and the majority of its population is dependent on rain-fed agricultural production for its livelihood (World Bank, 2006). However, estimated crop production is not close to fulfill the food requirements of the country due to the shortage of moisture in different parts of the country. In Ethiopia, irrigated agriculture is becoming increasingly important towards meeting the demands of food security, employment and poverty reduction. Improving this sector ensures food security, improves livelihoods and alleviates the poverty of the rural community in the country. Irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia (Awulachew *.et.al.*, 2005).

According to Robel (2008) one of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales, through river diversion, constructing micro dams, water harvesting structures, etc. have been indicated. Due to their relatively small investment cost, ease of construction, simplicity of operation & maintenance, small scale irrigation structures have been a strategic target of the country for achieving sustainable food security and self-sufficiency. The productivity of these irrigation schemes fully depends on the hydraulic functioning of intake, weir and main canal structures (stilling basins, drop structures, cross structures, etc.). When these structures do not perform well for the intended designed function, the performance of the structures would be damaging rather than productive.

The study area, Humbo Woreda, is one of the Woreda of Wolaita Zone of Southern Nations Nationalities and People Regional State. Humbo Woreda has both traditional and modern irrigation systems. A Traditional irrigation system has a long history in the district. Currently, there are a number of traditional and modern irrigation systems practiced in the district. Even though, the total potential area for irrigation was not exactly known, about 400 hectare is currently under irrigation with a total beneficiary of 480 households. This study was aimed at investigating the problems of small scale Irrigation schemes by emphasizing on irrigation schemes found in Humbo Woreda of Wolaita administrative Zone of SNNPRS, specifically; Bossa and Ella small scale irrigation schemes.

1.2. Statement of the problem

In Ethiopia, agricultural production mainly depends on rainfall. In addition, drought is becoming frequent and many people have been repeatedly exposed to hunger and famine. To alleviate the deep-rooted poverty at household level, the Ethiopian government is practicing different drought-proofing strategies. Among these strategies development of small scale irrigation for the farmers is the one. Small scale irrigation is one of the important pillars of the food security strategy of Ethiopian government that designed to promote the food production of small holder farmers (Awulachew *.et.al,* 2005).

Ethiopia has currently embarked to an accelerated irrigation development plan, in which the irrigated land is planned to be increased to three folds in five years. Apparently, expansion of irrigated land through new irrigation developments is relevant in Ethiopia in view of its underutilized potentials of land and water. However, ensuring the sustainability of the existing schemes is equally vital, which is clearly overlooked in Ethiopia. The majority of operational irrigation schemes in the country are characterized by a poor level of technical, hydraulic, operational and service delivery performance. Shortcomings include inadequate irrigation scheduling, inadequate operation plan, water logging and salinization, lack of adequate institutional setups for management, inadequate physical water control facilities, canal sedimentation and lack of adequate maintenance, lack of appropriate asset management, etc.

Some of these challenges are critical to small-scale community- managed schemes, while others are fundamental to large-scale schemes (Zeleke A, 2015).

The major problem related with irrigation development is also their negative impact on the environment and human health. Irrigation projects have the potential to degrade the land, the soil and waste the valuable resource water if they are mismanaged. In recognition of both the benefit and hazards assessment and evaluation of irrigation schemes performance has now become a paramount importance not only to point out where the problem lies but also helps to identify alternatives that may be both effective and feasible in improving system performance. (Agegnehu K., 2015).

Besides the poor performance of irrigation projects in the country, evaluation of irrigation projects is not common: lack of knowledge and tools used to assess the performance of projects adds to the problem. But now, different indicators have developed used to assess hydrological, agronomic and financial performance of irrigation system. Which are helpful to determine the conditions of the system and proper functioning of its elements? And it was attempted to apply this set of qualified indicators in to the two small scale irrigation schemes of Ella and Bossa irrigation. CBIWM (community based Irrigation Water Management) focuses on the collective management of irrigation water to improve human well-being and poverty reduction. In Ethiopia it is not well structured to manage small-scale irrigation scheme efficiently and proficiently. The two community managed small scale irrigation are found in SNNPR state Wolaita Zone in Humbo woreda. Farmer follows traditional farming practice **(**Agegnehu K., 2015**)**.

However, according to the maintenance document (WZWME, 2019), both Ella and Bossa schemes were irrigating 148ha and 136ha of land respectively, based on the amount of water resource available in the project area, the schemes were serving below their full capacity. The reason of not serving fully was due to various problems that need to be identified and evaluated.

There were various studies conducted at Wereda level on the impacts of SSI on livelihood (Ermias *et al*, 2015) and challenges and opportunities of SSI systems (Abebaw A. and Mesfin T., 2016). As far as our knowledge concerned, studies on problem identification were seldom conducted on the schemes.

1.3. Objectives of the Study

1.3.1. Main Objective

The general objective of this study is to investigate performance of the Ella and Bossa small scale irrigation schemes.

1.3.2. Specific Objectives

- ✓ To estimate the performance of Ella and Bossa irrigation schemes in the Humbo woreda SNNPRS.
- ✓ To compare the performance of the two schemes.
- ✓ To identify the operational problems of the schemes.

1.4. Research Question

To address the objectives the following research questions are developed.

- What is the current status of irrigation schemes in the study area?
- Which scheme is comparatively performing well?
- What are the major problems of existing small scale irrigation schemes?

1.5. Significance of the Study

This study will provide an input to planning, designing, constructing, managing and operating, small scale irrigation projects of the country development program. It also detects the problem of the study area to come up with suitable irrigation water administration.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Irrigation Development in Ethiopia

Traditional irrigation has a very old history in Ethiopia, especially in some parts of the country like Konso (Alemu, 2017). As Deribe, 2008 wrote, traditional irrigation system has been practiced for centuries in highlands of the country. These traditional irrigation systems were developed and managed through forming a water user's association for functions of construction, water allocation, operation and maintenance and were headed by individuals (Belay and Bewket, 2013). This association comprises up to 200 users grouped into 20 to 30 groups of farmers who share a common main canal or its branches (Yohannes *et al*., 2017). Based on the above discussions, the exact time when irrigation was started in Ethiopia remains uninvestigated regardless of routinely saying "irrigation was started in Ethiopia during ancient times" (Awlachew *et al*., 2007; Makombe *et al*., 2007;Hagos *et al.,* 2009; Bacha *et al*., 2011).

According to MoA, 2011a; Bekele *et al*., 2012, Modern irrigation was started in the early 1950's by the bilateral agreement between the government of Ethiopia and the Dutch company jointly known as HVA-Ethiopia sugar cane plantation. The rift valley is a place where modern irrigation in Ethiopia starts especially in the Awash River Basin at which adoption of pump irrigation commences. During the imperial regime, the main objective of irrigation was to provide industrial crops to the growing agro-industries in the country, many of which were controlled by foreign interests, and to increase export earnings (Gebremedhin and Pedon, 2002).

In Ethiopia, there were modern water storage and water management systems for irrigation purposes (MOE). This includes water diversion schemes, water storage dams, micro irrigation systems, rainwater harvesting and shallow ground water harvesting techniques. These systems make use of different water drawing irrigation technologies for lifting, conveying and applying irrigation water for irrigation uses. Night water storage facilities, Treadle pumps for lifting water, smallholder drip systems and micro sprinklers for irrigation application are used among others (MoA, 2011a).

According to Awulachew et al. (2007) explained that, irrigated agriculture was started in Ethiopia in the upper Awash Valley with the objective of producing industrial crops as sugarcane, cotton and horticultural crops on a large-scale basis, explained in a remarkable emergence of irrigation development and establishment of agro-industrial centers. This was due to taking an advantage of the construction of Koka dam aimed as a reservoir irrigation water supply, flood control and hydropower generation. After the fall of the imperial regime, the all large–scale irrigation schemes were nationalized by the military government and handed over to the Ministry of State Farms. Most of the landlord based small scale irrigation schemes also fell into the hands of producer cooperatives.

The military government also gave much emphasis to large-scale irrigation system schemes which were used by the nationalized agro-industrial and agricultural enterprises. In all these times the importance of small-scale irrigation was marginalized. It was after the devastating famine of 1984/85 that the government showed some interest on small-scale irrigation system. In response to these catastrophic droughts Irrigation Development Department (IDD) was established in the Ministry of Agriculture (MOA).However, only 35 small-scale projects were constructed until 1991(ibid).

2.2. Irrigation Water Control and Management

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 (Salman *et al*, 1999). 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 DeWrachien, 2002).

2.2.1. Irrigation Water Management

Water management and control depends largely on proper operation and maintenance of an irrigation development project. It has been seen that without good and efficient operation and maintenance, it is not possible to get desired result. Water management is the integrated process of intake, conveyance regulation, measurement distribution, application and use of irrigation water at the farmer's field and drainage of excess water from farmer’s field with proper amounts and at the right time for the purpose of increasing crop production (Das Gupta, 2005).

According to Wil and Vander, 1994 described the management of irrigation systems aims to achieve optimal crop production and efficient water use or in other term a reliable, predictable and equitable irrigation water supply to farmers. It is widely known that the performance of irrigation systems is below their expectation and potential. Inequity of water distribution occurs very often. Farmers are not sure when and how much water they can expect, which leads to very little cooperation and involvement in irrigation management and limited contribution to operation and maintenance costs.

The function of the conveyance and distribution systems services should provide sufficient water in a timely manner so that it can be used efficiently for crop production. Reliability and efficiency are then keywords for a modernization plan. The reliability of an irrigation service is the degree to which the irrigation system and its water deliveries conform to the expectations of the users. A reliable service allows efficient irrigation management within the constraints of the system (Playan and Mateos, 2004).

According to Vidhya et al., 2002 described a good management, proper and timely application of water may result in better yield and reduction in drainage problems. Irrigation water management has become a central issue in many countries, in particular after recent studies, which revealed the disappointing performance of many irrigation schemes.

Inefficient water use and inadequate water management, both at farm and scheme level mean much less area can be irrigated than planned and agricultural production falls well below target (Mehta, 1994). The responsibility for the management of the on-farm water distribution and the water application belongs to an individual farmer. The management is responsible for the operation and maintenance of the irrigation and drainage system.

Managing an irrigation system is not a simple task. Many different parties are involved; each with their own interests, however information on irrigation water management in a detailed scale like at country level is not common due to the lack of data, reliability and accessibility of the data (Merdun and DeIrmenci, 2004).

Irrigation management activities have both technical and social dimensions (Mollinga, 2003).These include control structure activities (design, construction, operation and maintenance), water use activities (acquisition, allocation, distribution and drainage), and organizational activities (decision making, resource mobilization, communication and conflict management). Further Mollinga, 2003 classifies irrigation management functions into four types viz. planning, organizing, leading and controlling. These tasks and activities should be properly coordinated and managed in irrigation systems.

2.2.2. Regulation of Flow Discharge and Water levels

According to (Shiberu and Hailu, 2011) irrigation scheme flows are controlled with the help of hydraulic structures and water reaches the fields at the proper time and in the quantities needed. Canal structure is needed to execute the necessary tasks to manage and control the infrastructures (Ertsen, 2005). According to Kraatz and Mahajan (1975) the water level and velocity control structures comprise a group of engineering works installed in open canal irrigation networks designed to regulate the water level in a canal, to control the quantity of water passing through it, to dissipate energy and enable water to be delivered accurately and safely to the fields without causing erosion. Such structures include checks or cross-regulators, drops (or falls) and chutes.

Water control refers to the ability of the system to distribute, apply or remove water at the right time, in the right quantity and at the right place (Shiberu, 2011). The main objectives of water control in an irrigation project are to deliver reliability (temporal), adequacy (volume balance, including seepage, operational and application losses) and equitable water to irrigation fields (spatial parameters) (Lowdermilk, 1981). In view of its aim, an irrigation system has to be planned, constructed, operated and managed in a way that the entire farm fields in the command area will receive and discharge water in an appropriate, conveniently arranged and adjustable manner (Depeweg, 1999).

According to Shiberu (2011) described the irrigation water measurement is an essential element for its fair distribution and economical use. Measurement serves to ensure the maintenance of proper delivery schedules, to determine the amounts of water delivered and to single out anomalies in distribution. According to Ertsen (2005) by means of weirs, dams, canals and other constructions, the spatial and temporal distribution of water is regulated.

An important aspect of water control relates to the temporal and spatial distribution of water or in other words the modification of an (agriculturally) unfavorable timing of watering in the annual cultivation cycle (Shiberu, 2011). Unfavorable timing includes both the transfer of water to overcome shortages (irrigation) and to remove excess water (drainage) (ibid). The collection, control, allocation and distribution of water to groups of fields and producers are the core processes of an irrigation system. Irrigation systems collect; transport and distribute water for agricultural production with the goal to supply the root zones of the cultivated crops with the necessary amount of water (ibid).

2.3. Role of Irrigation in Feeding the World

Water plays a critical role in food production. Improved moisture control and irrigation are essential to achieve estimated 80% of the additional production required to meet the demands of the future.

As described by Burt and Styles (1999), the major agricultural use of water is used for irrigation, which, thus, is affected by decreased supply. Hence, innovations are needed to increase the efficiency of use of the water that is available. Better management of agricultural water for increased productivity and efficiency, “More crop per drop”, are of vital importance. A two pronged strategy is needed to increase food production through irrigation.

According to Walker, (1989), many civilizations have been dependent on irrigated agriculture to provide the basis of their society and enhance the security of their people. As little as 15-20 percent of the world wide total cultivated area is irrigated. Comparing yields obtained from irrigated and non-irrigated farms, relatively small fraction of irrigated agriculture is contributing as much as 30-40 percent of gross agricultural output. Irrigation in arid areas of the world besides providing moisture supply to plant growth which also transports essential nutrients, it supplies water to leach or dilute salts in the soil.

Again Walker, (1989) described irrigation also benefits croplands through cooling the soil and the atmosphere to create a more favorable environment for plant growth. Irrigation may prevent severe frost damage to orchards, citrus nurseries, straw barriers, ferns, and subtropical fruits. If fruit trees were severely damaged, many years would be required to re-establish them. Irrigation is also used to bring soil moisture to the desired moisture level to prepare a seedbed after extensive periods of drought. Irrigation also enables controlling high plant temperatures by wetting the foliage, and increasing soil moisture to permit harvesting root crops such as sugar beets, potatoes and peanuts.

2.4. Irrigation Management Experience in Ethiopia

Irrigation development is a key for sustainable and reliable agricultural development which leads to overall development in Ethiopia (Makombe *et al*, 2011). According to recent classification by the MoWR (2002), irrigation schemes in Ethiopia are organized in four different ways on the basis of size and type of control or management:-

- ✓ Traditional small-scale schemes of up to 100 ha, built and operated by farmers in local communities;
- ✓ Modern communal schemes with the discharge that can water up to 200 ha, built by government agencies with farmer participation;
- ✓ Modern private schemes of up to 2000 ha; and
- ✓ Public schemes of over 3,000 ha, owned and operated by public enterprises such as state farms.

WUAs have long existed to manage traditional SSI schemes of up to100ha (ibid). They are generally well organized and effectively operated by farmers. The associations handle construction, water allocation, operation and maintenance functions with government technical and material support (MOWR, 2002).

However, those smallholder farmers who practiced traditional irrigation were denied proper support from government in order to upgrade irrigation systems (Dessalegn, 1999). The modern irrigation development policies and initiatives during the Imperial regime (second half of the 1950s) and the experience during the military regime (since 1975) were also not in favor of small-scale irrigators (Dessalegn, 1999). Almost all SSIS built after 1975 were made into producers' cooperatives (FAO: 1995). The attempts to SSIS development were also failed because the irrigation systems were denied operational autonomy and guided by undemocratic guidelines (Desalegn, 1999 and Woldeab, 2003), which were top down in approach. Under the centralized governmental management, operations and maintenance activities were also usually inadequately performed (MOWR, 2002).

The government in power also appears to be committed to the promotion of irrigation .Government policy in irrigation consists, among others, channeling direct support to farmers since the1991 government reform (FAO, 1995). The status of producers' cooperatives has been redefined with a consequence for irrigation management (FAO, 1995). The Farmers/communities are now forming their own organizational set up (WUAs) for own and autonomous management of irrigation schemes with support from the government and NGOs (FAO, 1995; MOWR, 2002).

In Oromia Region too, almost all schemes operation is fully left to the water committee. But still the (SSIS) suffer by multifaceted problems, including management and organizational problems, lack of access to credit and input and marketing facility (Rahmato,1999).

The schemes were found to be inefficient (economically), technically the structures deteriorated before their service life and some of them left unused (OIDA, 2000). In this regard (Dejene, 2015) argue that inefficient and underutilization of available capacity of the schemes in Ethiopia arises from giving more emphasis to technical aspects and less emphasis to the managerial and institutional aspects.

2.5. Challenges of Small Scale Irrigation Management

There have been many researches to identify challenges to the introduction, use and development of irrigation technologies. Doss (2006) and Adeoti (2008**)** disclosed important factors affecting the adoption and attitudes of farmers towards using the new technology. Some of them include government policies, technological changes, market forces, environmental forces, demographic factors, institutional factors and delivery mechanisms in general.

Based on the study conducted in Ghana in 2011 by Daniel, some causes of underutilization are identified as: non-adherence to decisions taken during the project planning stages, poor construction work, low technical capacity of agricultural extension agents, and weak management of Water User Associations. Under-utilization can be minimized by involving farmers in the irrigation planning process, and the creation of an enabling environment whereby farmers produce efficiently and have access to markets for their crops.

Another study conducted by Adetola, (2009) in Ghana obtained data from 108 farmers, i.e. 52 adopters of irrigation technology and 58 non-adopters; the study showed that availability of labor and numbers of extension visits per year are factors that can affect the adoption and utilization of irrigation technologies.

Low utilization of some small-scale irrigation technology is related to a number of issues such as limited capacity of farmers, institutional instability, defective project design and lack of adequate community consultation during planning (Awulachew, 2006). But, in contrary to the former findings, David, S. and David, Z, (2000) stated that farmers are uncertain about the properties and performance of new technology, and that these uncertainties lead to low exploitation of irrigation technologies. The main factors limiting the farmers from utilizing irrigation technologies to the desirable extent are low education level, family size, farming experience, availability of markets, and frequency of contacting extension officer (Justine Liberio, 2012).

Nevertheless, results from empirical studies from Selected Localities of Maharashtra and Gujarat States of India by Regassa *et al.* (2005) revealed that ownership of dug wells and bore wells had a strong effect on the probability of execution of irrigation technologies in both states. This is due to well owners having a high degree of control over the water source and the motivation to use the available water in the wells efficiently. Concerning the age of farmers adopting the new technologies, and contradictory to many studies, Regassa *et al*. (2005) found that age has no significant role since the older farmers have a lower chance of acceptance of new innovations and technologies before going to utilize.

Farah and Bahaman (2013), in their study in titled Factors Impinging Farmers‟ Use of Agriculture Technology in Malaysia, concluded that farmers‟ perceptions and levels of education, as well as extension-workers‟ knowledge, the management of the extension programme, and the physical conditions of the area, are all factors that affect technology adoption and use among farmers.

Water Source scarcity is the main challenge in utilization of irrigation technologies; so, at the time of scheduling and development of an irrigation project, source(s) of water should be identified, to ensure a continuous water supply. Furthermore, he recommended that in water resource development, some factors are essential; he listed harmonization of the various demands for water, establishment of irrigation priority rights between upstream and downstream users, and consideration of the rights of the existing users of water from flooding - which may be modified by dams(Ali.H, 2010).

From their study in Ghana, Gyasiet *et al.* (2006 cited in Nhundu, k. and Mushunje, 2011) concluded that access of higher wages or other options outside the schemes increase the opportunity cost of labor and reduce the incentive for household’s participation in irrigation programs. In addition to that uncommitted, non-transparent and rent-seeking attitude of management are publicized to be an important concern that can hinder the interest of households to engage in irrigation schemes.

The encounters be able to remain defined as technical limitations and information gaps such as:-

- ✓ Scheme based approach rather than area/catchments based approach for the development of SSI Schemes,
- ✓ Inadequate baseline data and information on the development of water resources,

- ✓ Lack of experience in design, construction and supervision of quality irrigation projects,
- ✓ Low productivity of existing irrigation schemes,
- ✓ Inadequate awareness of irrigation water management as in irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities,
- ✓ Inadequate knowledge on improved and diversified irrigation agronomic practices,
- ✓ Shortage of basic technical knowledge on irrigation pumps, drip irrigation system, sprinkler irrigations, surface and spate irrigation methods
- ✓ Inadequate community involvement and consultation in scheme planning, construction and implementation of irrigation development,
- ✓ Poor economic background of users for irrigation infrastructure development, to access irrigation technologies and agricultural inputs, where the price increment is not affordable to farmers (Kassa.H, 2008).

2.5.1. Insufficient technical skill

In many parts of the country; the farmers are practicing irrigation without essential knowhow on crop water need, water application method and irrigation interval Lack of knowledge of irrigation water management aspects has resulted in wastage of irrigation water, deterioration of some structures and water logging problems on some farms (Hundie, 2006).

Low capacity of farmers, lack of know-how in, and access to, the opportunities of irrigation technology; weak economic base of most farmers and the relatively high development costs involved in developing irrigation schemes are also the other key constraints (Tafese, 2003).

Poor irrigation scheduling/crop-water-requirement balance; inappropriate irrigation methods are widely recognized (MoA, 2011). All over the rural areas of Ethiopia; market access and marketing facilities are the major constraint influencing farmers' success (Adugna, 2014).

There is no rational place or customer for selling their produce. The middlemen and brokers were exploiting their benefit. It's not the market structure which determines price, but the brokers and merchants. The farmers have not the bargaining power (e.g, DoniKumbi schemes Oromia region). Input price is so match expensive. Market problems mainly related to irrigation agriculture are acute due to perishability of irrigation based agricultural commodities. Added to this lack of storage facilities and processing agro industries in many of the schemes caused a great loss. Price instability and lack of market are almost invariability confirmed as conspicuous major constraints to irrigated agriculture. Marketing cooperative were conspicuously missing or proved to be too ineffectual to reduce risks arising from price instability and marketing problems (e.g,Gedemso scheme in Oromia) (Seid, 2002; Dejene, *et al.*, 2008).

2.5.2. Poor Scheme Management

Many of the schemes in the Rift Valley Basin, Awash River Basin, Tekeze River Basin etc were under severe challenges of siltation and sedimentation. For instance, from five to eight years after the irrigation project of Awash was commenced salinity became very severe (Girma and Fentaw, 2003). The same source indicated that the main cause of salinity was poor irrigation water management. Inefficient erosion drainage systems along the canals has caused severe siltation problem (e.g., Tekeze basin in Tigray, Mintesinot, 2004). This in turn affected seasonality, labor efficiency and cropping pattern (e.g., Argeda scheme in Oromia).As a result, the community has been forced to invest their scarce labor at peak periods for removing siltation at least three times a year. Had it been calculated the labor cost is so much high since it demands a large number of people to work on cannel clearing for weeks. This also creates dalliance in cropping season. There was poor performance in managing water distribution in terms of the three indicators: adequacy, reliability and equity in water distribution in Gibe Lemu and Gambela-Terre basins; Oromia region (Dejene, *et al.,* 2008). Poor management of agricultural water leaves almost all part of the country highly susceptible to rainfall variability which depicts itself in terms of prolonged dry spells and droughts.

2.5.3. Socio-institutional constraints.

At all levels, there exists low institutional capacity which is critical to enhance development of SSI with respect to development planning, design, implementation, and operation and maintenance including irrigation advisory services (MoA, 2011). Water theft, conflict on land, and water distribution is a common scenario in many schemes. Despite, the WUAs have weak coordination skill to solve scheme related problems. Upper stream households were getting adequate water, whereas lower stream beneficiaries do not. As a result some sort of conflict and dissatisfaction was rising. However, the community has traditional means of negotiation.

The participation of women in WUAs is not satisfactory. The cattle crop integration is another challenging issue. Inequity in water distribution between locations, between socioeconomic groups in (e.g, Lemu and Gambela-Terre basins; Oromia region; are the social constraints (Dejene, *et al.,* 2008). Other institutional barriers include limited or no priority given to irrigation development during national and local planning and budgeting; poor management structures in place to support farmers and promote irrigation development. For example, the infrastructure to facilitate agricultural development is underdeveloped (Tafese, 2003; Hundie, 2006).

Poor coordination between institutions dealing with irrigation development: For example, there are no clear-cut duties and responsibilities between the Department of Agriculture and Department of Service Cooperative and Promotion (Seid, 2002). Inadequacy of extension support with respect to irrigation management is a common phenomenon for many schemes (Alemu, 2017). There is ample evidence from all regions that most of the failed projects are those implemented without sufficient and effective beneficiary consultation and participation (Alemu, 2017). Absence of sanction and poor coordination of water users association are the main administrative problems in Godino and Filtino schemes; Oromia region (Tesfaye, 2006).

2.6. Performance Evaluation of Irrigation Practice

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.

Kloezen, *et al.,* (1999) stated that effective irrigation management requires reliable performance assessment. Good farm irrigation management assures correct frequency of irrigations, correct application depth, uniform irrigation, minimum runoff, and minimum deep percolation except for that required for salt management, minimum erosion, and optimal return on irrigation investment (ibid).

According to Shiberu, (2011) 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 (ibid).

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 (Hailu, 2011). 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 (Walker, 1989).

The common efficiency terms used for on-farm irrigation system evaluation (internal performance 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).

2.6.1. Selected performance indicators

Furthermore IWMI established numerous indicators in each group of process and comparative performance indicators. Though for this study the following indicators have been selected:

2.6.1.1. Water delivery indicators

This comprises conveyance efficiency, Relative water supply and Relative irrigation supply.

a. Conveyance efficiency

According to Bos, (1997) conveyance efficiency is defined as the ratio of the amount of water delivered at the turnouts of the main irrigation conveyance network to the total amount of water diverted into the irrigation system or simply it is the ratio of outflow rate to inflow rate of a system. Conveyance efficiency represents the capability of a canal reached to carry water with loss, while the conveyance loss (L) is the amount of losses occurred in the specified length of canal reaches. It is one of closely related and commonly used output measures of performance that focus on the physical efficiency of water conveyance by the irrigation system.

Measuring the outflow over inflow ratio for single one month gives information to the system manager provided that a target value of the ratio is known. A regular replication of the measurement allows the assessment of the style of an indicator in time. This assists the manager in identifying trends that may need to be reversed before the remedial measures become too expensive or too complex.

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

b. Relative water supply (RWS)

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

c. Relative irrigation supply (RIS)

This indicator is useful to assess the degree of irrigation water stress or abundance in relation to irrigation demand. It is the inverse of irrigation efficiency presented by (Bos, 1997).This is the ratio of annual irrigation supply (which excludes rainfall) to annual irrigation demand. Irrigation water is a scarce resource in many irrigation schemes and is a major limitation for production. Both RWS and RIS relates supply to demand, and shows some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched. If the value greater than 1, it indicates water supply was beyond the water demand; if it is less than 1, the water supply was below the water demand. While if it is equal to 1, the supplied amount of water was sufficient to demand, i.e. neither surplus nor deficit. Most of the time it is better to have a RIS near 1 than a higher value.

However, care must be taken in the interpretation of results; an irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate appropriate use of available water; a lower RWS would actually be less desirable. Likewise, the value 0.8 may not represent a problem; rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water.

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

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

As Molden *et al.*, (1998) stated it contains evaluation of Output per unit irrigated cropped area ($/ha), Output per unit command area ($/ha), Output per unit irrigation water supply ($/m3), and Output per unit water consumed ($/m3).These "external" indicators provide the basis for comparison of irrigated agriculture performance. Where water is a limiting resource, output per unit water may be more important, whereas if land is a limitation relative to water, output per unit land may be more important.

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

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

Second, we note that the most common indicator of agricultural performance (yield per unit land, or more commonly just 'yield') is itself a gross indicator, unqualified by indications of input levels, soil type, or even variety. Despite this simplicity, yield serves many agriculturists as a fundamental indicator of performance.

2.6.1.3. Physical performance indicators

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

2.6.1.4. Financial indicators

Large irrigation investments are made in irrigation infrastructure, thus returns compared to investment in infrastructure are presented. We focus on water delivery infrastructure to be able to analyze.

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

This study was merely emphasis on gross return on investment; the indicator considers the production value and the total cost of infrastructure for each scheme. Policy makers are strongly interested in the returns to investments made. Likewise, researchers would like to be able to recommend systems that yield acceptable returns within a given environment.

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

2.7. Water User Management

Water is considered as free good to be available for everybody without any cost. Being in essence, a person has a right to use at every point in time of and space without discrimination. While irrigation is costly business in the terms of investment and other resources so it should have its own cost that would be reinvested, say for the maintenance and further development of the schemes. Even though theoretical experts try to match the demands of head and tail water users and put the mechanism of delivery to systems (blocks and units) , because it is free good and lack of awareness this will remain on the paper rather than practiced in the field (Girma, *et al,*. 2006).

2.8. Improvement Options of Small Scale Irrigation

In identifying the major factors which would contribute to the successful development of irrigation technologies throughout Ethiopia, (Passarelli, *et al,*. 2018) mentioned the following: the existence of a favorable natural environment, government policies, predominant presence of diverse and suitable agro-ecologies and abundant natural resources, the promising potential of improved technologies, and the government's commitment to improve the sector.

Additional factors mentioned by (Passarelli, *et al*,. 2018) were: the existence of a young generation with relatively better training and knowledge, an increasing need and interest among farmers to use new technologies, favorable markets and access to international markets. “We have fertile ground in which to plant the new irrigation technologies”, concluded DFID.

As (Kassa, 2008) suggest the basic prospect thoughts regarding irrigation expansions in Ethiopia are:-

(1) Rich water resources, climate and land Suitability.

(2) Availability of cheap labor.

(3) Availability of suitable lands for irrigation developments particularly at arid areas of the country.

(4) Weight and main concern are given to irrigation in the development and revolution plan of the country.

(5) Native knowledge and introduction of capable household water harvesting and micro-irrigation technologies.

(6) Government’s durable political commitment and reassurance to private sector and public enterprises participation in irrigation development.

Improving the efficiency of irrigation systems can reduce water loss due to deep percolation and runoff. Consequently, improving irrigation efficiency can reduce the amount of water and agricultural chemicals entering groundwater and surface draining systems.

Doss (2006) strongly advises that promoting the efficient use of water resources through irrigation technologies should be a major concern of developing countries‟ governments. The basic objective of promoting small-scale irrigation is to increase farmer’s involvement in the design, implementation, operation and maintenance of irrigation technologies (Carter and Howsam, 1994, cited in Niguse, 2014).

In Africa, public mobilization, assisting and motivating suppliers of modern technology, promotion through accessible media, and development and implementation of small-holder farmer-centered policies, have a significant role in irrigation technology development. In addition, research institutes have a great significance in information sharing and promotion of farm research, in partnership with the extension personnel and the local farmers (Takeshim, *et al.*, 2010).

According to Shiberu, (2011) the average conveyance efficiency is about 50% but it can be increased to 70- 90 % by minimizing the conveyance losses through adoption of appropriate measures. Therefore, in order to increase the water conveyance efficiency the following measures can be taken:

- ✓ Covering of canals, water ways and channels with impermeable materials;
- ✓ Consistent repairs of cracks, holes, burrows, damages and seepages in water control structures;
- ✓ Management of weed growth in the unlined canals, waterways and field channels

2.9. Organizational Setup of small Scale Irrigation

In accordance with the federal and regional policy framework for small-scale irrigation development in Ethiopia, "Kore Aba Lagas" are in charge of water allocation, distribution, observing the water rights of members, conflict management and coordination of maintenance activities (Dejene, 2015). One of the social requirements for successful irrigation is organization and management structure that suit the irrigation infrastructure (Mollinga, 2003; Woldeab, 2003).

Cultural bonds may equally foster mutual ties out of which such an institution can be built, and such natural social cohesion forms a strong basis upon which to form an institution (SAWAF, 2002). Executive committees, sub-committees and water user teams (WUTs) were formed at irrigation system and distribution levels [territory units (TUs)] to facilitate water control and coordination of maintenance activities. Problems of noncooperation can be minimized through giving strong emphasis to institutional arrangements which tend to be the outcome of collective choice (North, 1990; Ostrom, 2000; Cousins, 2000).

The associations need ongoing support, not just one-off training. Support should include the development of by-laws and mediation mechanisms for equitable and accountable distribution of water and improve the market power of small farmers. This includes supporting farmer organizations, cooperatives and contract farming arrangements, and installing crop storage facilities to allow bulk sales and reduce post-harvest losses. Ensure that irrigation development is accompanied by complementary investments in market development, transport infrastructure and communications in rural areas. Without these, irrigation development will bring limited returns and will not generate the desired rural growth. Provide ongoing support for farmers following construction of irrigation schemes. This should include agronomy training, marketing support, and support for management and maintenance of the irrigation scheme.

In addition, enabling institutional and organizational condition and good management of irrigation schemes is becoming increasingly recognized, as an essential means to achieve successful irrigated agriculture (Pavlov, 2004). However, past research has highlighted that underperformance and many problems of irrigation systems are based on shortcomings and weaknesses in institutional development and in the management of the schemes (Turral, 1995 and Pavlov, 2004).

Irrigation management or water control is thus the regulation and control of human behavior; implying social relation of power and competition (Mollinga, 2003). Hydraulic factors such as a decrease in water supply (scarcity) may increase conflict and competition among water users, with implication for social relation of power and management (Shimels, 2006). It is therefore crucial to investigate this component of the irrigation systems for understanding their limitations and strengths and to suggest ways for improvement.

2.10. Crop Water Requirement

The term 'water requirement of the crop' means the total quantity of water and the way in which a crop requires water, from the time it is sown to the time it is harvested (Garg, 1991). 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 evapotranspiration (Nuha and Henery, 2000). Crop water requirement is defined as the depth of water needed to meet the water loss through evapotranspiration of a disease free crop growing in a large field under a non-restricting soil condition, soil water, and fertility achieving full production potential under given growing environment (Allen *et al.,* 1998).

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). Based on the comparative studies of the reference evapotranspiration methods and recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the Penman Monteith equation has been adopted as the globally best performing method of estimating evapotranspiration (Smith *et al.,* 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 evapotranspiration (Nuha and Henery, 2000).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

Humbo Woreda, which is the study area of the present research work, is one of the 17 Woreda of Wolaita Zone of the SNNPR state. The Woreda is bordered by Soddo Zuriya Woreda in the north, ofa Woreda in the west, Hobicha Woreda in the north-east, Abela abaya in the south-east and in the south. The Humbo Woreda astronomically is located between 6.50 to 6.81º N Latitude and 37.57 to 38.04º E Longitude. It is located 397 km South-West of the capital city, Addis Ababa and 18 kilometres from Soddo, which is the administrative seat of Wolaita Zone. The Woreda is composed of 20 Kebele Administrations, of which 19 are rural and one is Urban.

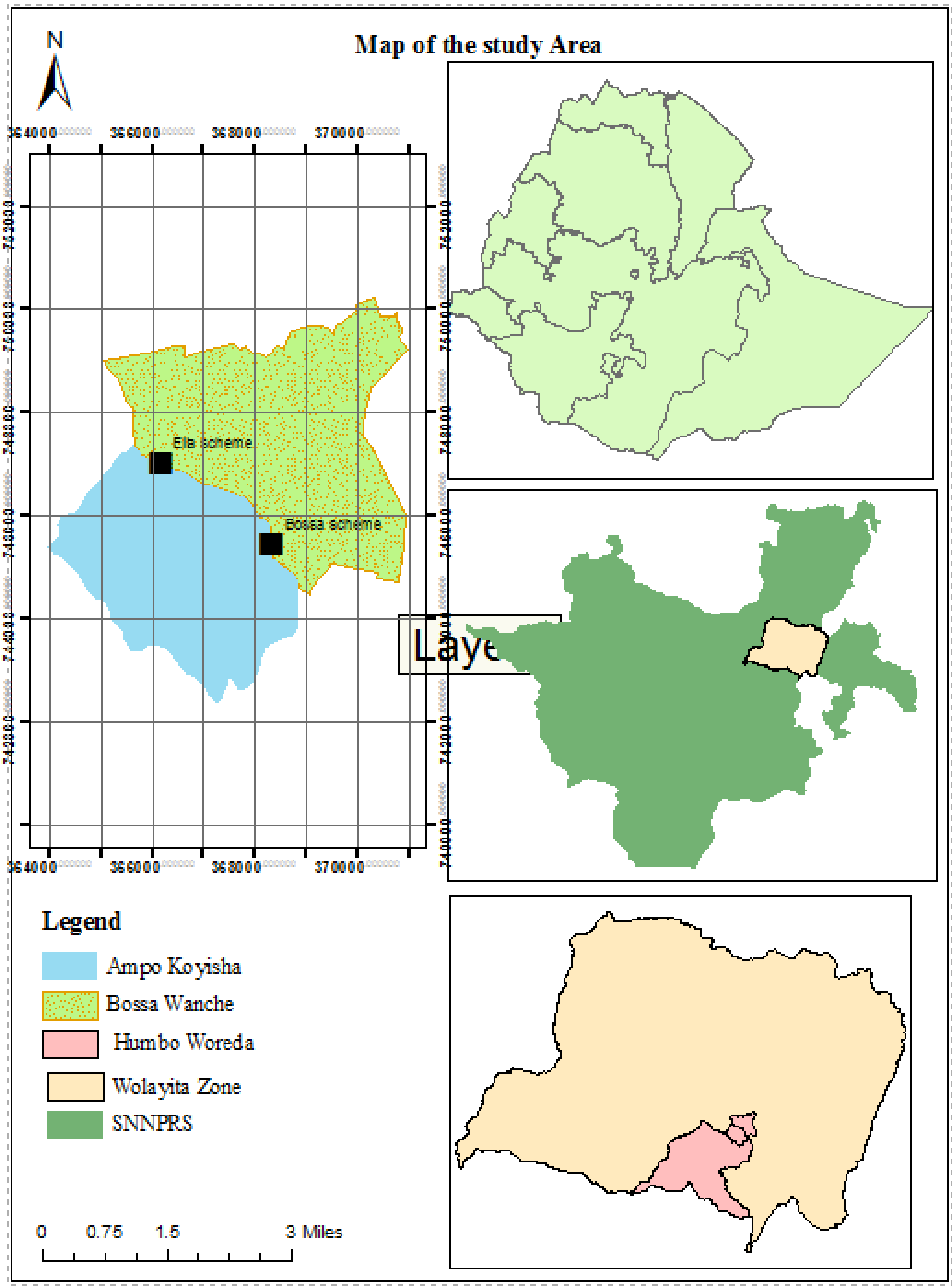

Figure 3.1. Map of the Study Area

3.1.2. Climate and hydrology

Considering the agro-climatic Zones, 11.11% of the Woreda falls under highland (Dega), 27.77% falls under mid-highland (Woina-Dega) and the remaining 61.12 % falls under lowland (Kolla). Mean annual temperature of the Woreda is 22.0ºC and mean annual rainfall is 1123.15 mm (WZFEDD, 2019).The area is categorized by bimodal rainfall season (June to September) and shorter rainy season (March to April).Hamesa and Lintalla Rivers are the permanent water sources which have considerable flow in dry and wet seasons.

3.1.3. Crops grown in the Woreda

The main crops produced in the Woreda are cereals such as maize, sorghum, teff, haricot beans; cash crops like coffee; root crops like sugar potato, Inset, and small vegetables like onions, cabbage, tomato; and fruits like banana, mango, avocado and others. However, due to severe soil erosion, fragmented land size, and erratic rainfall, crop production has been negatively affected. In the Woreda, farming is mainly rainfall dependent though inhabitants around rivers like Hamassa, use an irrigation system (WZFEDD, 2019).

3.1.4. Agricultural practice of the study area

The community performs mixed farming system. According to (WZFEDD, 2019), the total area of Humbo Woreda is 29,200ha and had a population of 65000 of which 42000 were male and 23000 were female in the year 2019. Out of the total population of the district, only 7,897 were urban dwellers and the rest 57103 were rural. This shows that the inhabitants of Humbo Woreda predominantly live in rural areas. The population of Humbo Woreda consists of different ethnic groups, though the overwhelming majority of the inhabitants belong to Wolaita ethnic group. With regard to economic activities, like the other Woredas of Wolaita Zone, agriculture (mainly crop and livestock production) is the most important economic sector in

Humbo Woreda. Livestock (e.g. cattle, sheep, goat, poultry, and donkey) also has an important place next to crop production in the economy of the inhabitants of the Woreda. Furthermore, other economic activities like handcraft industry, trade and others also play an important role in the life of the inhabitants of the Woreda. Humbo Woreda recurrently experiences food shortages. Poverty, hunger and increasing demand for agricultural land have driven local communities to over-exploit forest resources. Consequently, tree cutting for fuel-wood, charcoal making and construction material supply are livelihood activities of last resort that some people rely on to compensate periodical food shortages created by decline in agricultural production in the area over a long period of time(WZFEDD, 2019).

Irrigation water allocation of both schemes is rotational and unbroken that can be carried out by WUA with farmers but the most of the farmers cannot follow the procedures because of planting date of major crops is almost the same. According to the result from house hold survey government is the owner of irrigation scheme. All first design and construction cost was covered by government to Bossa scheme and Word vision to Ella scheme. The predominant water supply method to field plot is rotational while method of application is a furrow. There is irregular irrigation interval which varies from 6 to 8 days depending on the moisture content in the soil. There is enough water in the scheme but there is conflict on water distribution because of farmers not follow irrigation schedule and lack of know how about irrigation management. The farmers irrigated such type of crop, potato, cabbage, small vegetables and some cereal crops.

3.1.5. Description of irrigation schemes.

3.1.5.1. Selection of irrigation schemes

Among the 4 small-scale irrigation schemes in the district two modern schemes are selected based on accessibility of secondary data. These two irrigation schemes are representative for modern small-scale irrigation schemes in the District. The total number of households in the two irrigation schemes is 395, i.e. 175 in Bossa and 220 in Ella.

3.1.5.2. Bossa small scale irrigation scheme

Bossa irrigation scheme is located in the Bossa wanche kebele latitude of 36°79′67″, the longitude of 74°62′79″ with the altitude of 1659m. It was constructed and sponsored by PASIDP in 2000E.C. Irrigation method, water abstraction and source of water is a farm, diversion weir and river respectively. Design command area of the scheme is 180ha for the beneficiaries of male 150 and female 25 of the total of 175.

3.1.5.3. Ella small scale irrigation scheme

Ella small- scale irrigation scheme diversion weir head worksite is located in SNNPR, Wolaita Zone Humbo Woreda in Ampo koysha kebele, and the canal network and end-users are within Ampo koysha kebele were constructed in 1986 and sponsored by world vision non-governmental organization. Geographically the diversion weir of the project exists at UTM coordinates of 36°73′73″ and 74°62′86″E, elevation 1684m with the design command area of 200ha. The numbers of beneficiaries of the scheme are 187 male and 33 female with a total of 220. Drops, division boxes, lined and unlined canals, etc. hydraulics structures exist at scheme site.

3.1.6. Soil characteristics and crops grown in the projects area.

According to the woreda water and mine office and field observation the dominant soil textural class of the command areas is clay loamy in both schemes. In the project area, about 148ha and 136ha of land were developed in both Ella and Bossa irrigation schemes in the year of 2020/21 irrigation seasons respectively. The major crops under irrigation are maize, small vegetation and tomato in Ella scheme and maize, potato, and cabbage in Bossa scheme.

3.2. Data collection methods

This research was carried out starting from October to March; 2020/21 of the irrigation season. In this study quantitative and qualitative research approach; primary and secondary data have been gathered and engaged for the study purpose. The primary data were collected through household interviews, focus group discussions, key informant interviews, field observation and measurements. The secondary sources of data were collected from institutions involved in the development of small-scale irrigation such as the Bureau of Zonal and Woreda Water Resources, and Woreda Office of Agriculture and different publications and books.

3.2.1. Quantitative Data

The quantitative data were collected to identify trials related to water management by field observation and measurement such as water delivery performance indicators, physical (sustainability) performance indicators, agricultural performance indicators and financial indicator.

3.2.1.1. Water delivery performance.

An irrigation system is a set of physical and institutional elements employed to acquire water from a naturally concentrated sources, to facilitate and control the movement of the water from its source to the root zone of land devoted to the production of agricultural crops (Small and

Svendsen, 1990). A properly operated and maintained irrigation system delivers, in timely fashion, an adequate amount of water to the point of use. Indicators, used to measure the adequacy and efficiency of water delivery, are described below:

a) Relative water supply *(RWS):* This relates the total volume of water applied (irrigation water plus total rainfall) to the volume of water required by the crops during the period. Total volumes of water supplied during the period in the case of large-scale schemes were obtained from the respective scheme administration. The volume of water demanded by the crops was estimated using meteorological data obtained from meteorological stations of the schemes and CROPWAT 8 (FAO, 1998).

$$RWS = \frac{Total\ water\ supply}{Crop\ demand} \qquad 3.1$$

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

$$RIS = \frac{Irrigation\ supply}{Irrigation\ demand} \qquad 3.2$$

c) Conveyance efficiency (Ec):

Conveyance efficiency was measured at main, and secondary canal at some distance both lined and unlined canal at diversion point. The conveyance efficiency was measured on the main canal by measuring discharge at six different points. The conveyance efficiency was measured repeatedly to minimize errors and the discharge was calculated by the floating method in which the velocity of the water flowing in the main canal was estimated by timing the passage over a predetermined distance of the canal of some material floating on the water surface. The estimated velocity then was multiplied by the cross sectional area of the particular section of the canal to obtain the discharge.

The first measurement of discharge was conducted in the upper position of the main canal. In this canal section, the cross-section of the channel was lined, uniform and rectangular in shape. Since the main canal had a rectangular lined section for part of the system, the test site was ideal for flow measurement. The length of the canal section considered for discharge measurement was taken. The width and depth of water flow in the canal was measured repeatedly and average was taken. Floating material (high land bottle) was put on the upper end of this canal section and the time it took to reach the length of the canal section was recorded. This test was replicated three times and the average time was used. To obtain a per meter velocity, the total length of the section was divided by the average time obtained. To obtain average discharge flowing in the canal average velocity was multiplied by area of the canal. By dividing the second discharge by first discharge conveyance efficiency of the canal was determined.

This measurement was taken by put high land bottle at the center of water flow in canal and record the time elapsed to reach the end point at specific length. It was computed as follows (Ramulu, 1998):

$$Ec = \frac{Vd}{Vc} * 100 \qquad 3.3$$

Where: Ec = Water conveyance efficiency (%)

Vd = water flowing into the canal section (m^3 /s)

Vc = water flowing out of the section (m^3/s)

In the water conveyance systems water loss occur as evaporation, seepage in unlined channels, through transpiration and leakage through the water control structures in the conveyance system.

3.2.1.2. Physical performance indicators

We have used three major physical indicators to assess the current status of irrigation at schemes level. These are described below.

a. Relative irrigated area: This is the total area under irrigation versus total designed command areas of already implemented irrigation projects during a particular year or averaged over years in the scheme.

$$\text{Relative irrigated area} = \frac{\text{area irrigated}}{\text{area commaned}} (\text{ha/ ha}) \qquad 3.4$$

Where: Command area is the nominal or design area to be irrigated, and irrigated area is the sum of the areas under irrigation during the time period of analysis.

b. Beneficiaries target performance: This is the ratio of actual number of beneficiaries using irrigation schemes and planned or targeted number of beneficiaries.

$$\text{BTP} = \frac{\text{Actual benefitiaries}}{\text{planned benefitiaries}} (\text{No./No.} \qquad 3.5$$

Where: BTP is the actual number of beneficiaries, and planned number of beneficiaries are total number of beneficiaries targeted in the project.

c. Sustainability of irrigated area

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

$$\text{Sustainability of irrigated area} = \frac{\text{area irrigated currently}}{\text{area irrigated initially}} (\text{ha/ ha}) \qquad 3.6$$

Where: currently irrigated area is the area under the irrigation during the analysis of this study and initially irrigated area is an area under irrigation at the beginning of the project.

3.2.1.3. Agricultural output indicators

Agricultural output indicators can be subdivided into land productivity and water productivity indicators. The outputs of agricultural production in this paper were based on local prices.

1. **Output per unit irrigated cropped area (Birr/ha)**

The output per unit irrigated cropped area (output per unit harvested area) quantifies the total value of agricultural production per unit of area harvested during the period of analysis. The seasonal harvested area depends on the intensity of cropping (irrigation intensity). This indicator is not affected by the intensity of cropping (irrigation). However, it can also indirectly indicate the degree of irrigation water availability. In addition to water availability, soil type and fertility, land suitability, crop variety and agricultural inputs do have significant impact on output and hence on land productivity. It was given by:

$$\text{OPUIA} = \frac{\text{value of seasonal prodaction}}{\text{area harvested}}(\text{birr/ha}) \qquad 3.7$$

Where: Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices annually and harvested area is the total area under the crop.

2. **Output per unit command area (Birr/ha)**

The output per unit command area is the value of agricultural production per unit of nominal area which can be irrigated. Smaller values of this indicator can also imply, although not necessarily, less intensive irrigation and vice versa. It is particularly important where land is a constraining resource for production. It is given as:

$$\text{OPUCA} = \frac{\text{value of seasonal prodaction}}{\text{nominal area}}(\text{birr/ ha}) \qquad 3.8$$

Where: the nominal is Command area or design area to be irrigated, and Irrigated area is the sum of the areas under irrigation during the time period of analysis and value of annual Production is the output of the irrigated area.

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

The output per unit irrigation water supply tells on how well the total annual diverted irrigation water from a source is productive. Irrigation water supply includes conveyance (seepage) losses in canals, and hence it is generally measured at the intake from the source or at diversion. In areas where water is scarce, water management aims to increase the output per drop of irrigation water:

$$\mathbf{OPUIS} = \frac{\text{value of seasonal prodaction}}{\text{supply irrigation seasonal diverted}}(\text{birr/m3}) \qquad 3.9$$

Where: Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices annually and Diverted irrigation supply is the volume of surface irrigation water diverted to the command area.

4. Output per unit water consumed (Birr/m^3)

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

$$\mathbf{OPUWC} = \frac{\text{value of seasonal prodaction}}{\text{water consumed by ET}}(\text{birr/m3} \qquad 3.10$$

Where: Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices annually and Volume of water consumed by ET is the actual evapotranspiration of crops.

3.2.1.4. Financial indicators

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

$$GIR\ (\%) = Gross\ Value\ of\ Production / Cost\ of\ irrigation\ Infrastructure \quad 3.11$$

Where: Gross value of production is the output production value of the irrigation projects (ETB/ha) Cost of irrigation infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the production (ETB/ha).

In both Ella and Bossa schemes couldn't access the design document and the information was gotten from Humbo district Water mine and energy Office and Zonal level irrigation experts.

3.2.2. Qualitative Data

The qualitative data was collected by directing questionnaires for house hold interview, focus group discussions and key informants interview.

3.2.2.1. Designing Questionnaire

Before designing the questionnaires field observation was taken to visit irrigation system on September, 2020 and casual communication was done with some farmers, development agent and WUA to design questionnaires according to meet the objectives of this study. Based on the information gathered from field observation and casual interviews questionnaire was developed and pre tested before running questioners. Questions were prepared to get enough information about the irrigation scheme regarding this study.

The questionnaire generally was include questions that indicate the problems of the causes of failure and/ or under performance of small scale irrigation schemes having two parts, such as physical and socio economic, planning and institutional parts.

Functionality of irrigation schemes, structures design system, damage of weir components, condition of distribution structures, problems of flooding, erosion, siltation of canal, weed growth in the canal and on farm, irrigation practices and type of crops grown and other relevant data were detected at the field and pictures were taken as assisting tools.

3.2.2.2. Sample size determination

The recent number of Ella and Bossa irrigation water users households' number was 220 and 175 from those 69 and 64 numbers of households were selected for this study respectively. Single population proportion formula and purposive sampling techniques were applied for sample selection. Yamane (1967) provides a simplified formula to calculate sample sizes.

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

Where: n is the sample size, N is the population size (total households); e is the level of error margin (0.1).

Based on the above equation, the minimum numbers of sample households selected are 133 from both schemes. Purposive sampling method was used for the selection of farmers, key informants, and focus group discussion members. The WUA member's registries were used as a sampling frame.

3.2.2.3. Focus group and key informants discussions

The focus group discussion was held with representative farmers who are the first during irrigation project and model irrigators which have farm plot at head, middle and tail to get all information about all organization activities. Accordingly eight irrigator's were selected from each scheme. To prevent bias women irrigators were also included for the discussion. The discussion was based on irrigation water sustainability, water diversion tool, irrigation schedule, water fairness, and challenging faced on all irrigation activities starting from water diversion from main source to field plot and agricultural seed plant to product trades.

Key informant interview was conducted with development agents, relevant Woreda irrigation experts and WUA and role model farmers. Discussion was conducted based on all activities of irrigation management such as water conveyance system, and sustainability of irrigation scheme, the major problems faced and enhancement opportunities of the irrigation scheme.

3.3. Cropping Pattern of the Irrigation Schemes

Cropping pattern of a certain area mainly depends on availability of water, type of soil and land to be irrigated, climatic conditions, and also value of produce/market/ and socioeconomic aspects. From the household survey results, in both schemes of the respondents, revealed that they have been practiced single cropping system in the irrigation seasons; i.e. the first is from November to March. Maize, small vegetables, and tomato were the main crops cultivated in the irrigation season in Ella whereas, maize, potato and cabbage were the main crops cultivated in the irrigation season in Bossa scheme.

S. No	Types of Crops	Area (%)	Area (ha)	Planting date	LGP (days)
1	Maize	44.12	60	20/11/2020	145
2	Potato	22.06	30	15/12/2020	110
3	Cabbage	33.82	46	15/1/2020	110
	Total		**136**		

Table 3.1.: Crops, area coverage and LGP at Bossa SSI schemes

S. No	Types of Crops	Area (%)	Area (ha)	Planting Date	LGP (days)
1	Maize	50.68	75	13/11/2020	145
2	Small vegetation	27.03	40	17/12/2020	110
3	Tomato	22.30	33	15/1/2020	110
4	**Total**		**148**		

Table 3.2.: Crops, area coverage and LGP at Ella SSI schemes

3.4.Discharge measurement

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.

3.4.1.Canals discharge measurement

The discharge in the canal was measured with floating method. The method consists of estimating the average flow velocity and measuring the area of the cross-section, called the ‘wetted cross-section’. The discharge was calculated by continuity equation below.

$$Q = V * A \quad 3.13$$

Where: Q: the discharge (m^3/s)

V: the average flow velocity (m/s)

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

I. Average flow velocity

To estimate the average flow velocity, the flow velocity of the water at the surface, the surface velocity, Vs. was first determined. The surface velocity was determined by measuring the time it takes for a floating object along the canal. The floating object was placed in the center of a canal and the time measurement was repeated three 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 determine the velocity of surface water of the channel, the length of trail section was divided by the average time taken by the float cross it. Since the velocity of the float on the surface of the water was greater than the average velocity of the stream, it was necessary to correct the measurement by multiplying by a constant factor (velocity correction factor) which was usually assumed to be 0.85 (Harrelson, 1994). To obtain the rate of flow, this average velocity (measured velocity * correction factor) was multiplied by the average cross-sectional area of the stream.

To compute the surface velocity, Vs the selected length, L was divided by the travel time, t:

$$\mathrm{Vs} = \frac{\mathrm{L}}{\mathrm{t}} \qquad (3.14)$$

Where: Vs: the surface velocity (m/s)

L: the distance in meters between selected points and

t: the travel time in seconds between selected points

The surface velocity must be reduced in order to obtain the average velocity, because surfacewater flows faster than subsurface water.

$$\mathrm{V} = 0.85 * \mathrm{Vs} \text{------} (3.15)$$

Where: V: the average flow velocity (m/s); Vs: the surface velocity (m/s) found from equation (3.3).

II. Area of the wetted cross-section

For measuring the flow with the floating method, the area of the wetted cross-section (A) was determined for a selected straight and uniform portion of the canal. The rectangular cross sectional area was calculated from measurements of the surface water width and the water depth using equation 3.5.

$$A = w1 * h1 \qquad 3.16$$

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

w1: surface water width (m)

h1: water depth (m)

The area of the cross-section was measured three times to get the average area.

3.5. Data Analysis

Statistical Package for the Social Sciences (SPSS) current version, IBM SPSS Statistics software was used to analyze the collected data from household interviews. Descriptive types of statistics such as percentage, and frequencies, were used to review and classify the data. CROPWAT.8.0 software was used to investigate the crop water requirements for major irrigated crops.

SPSS Statistics is a software package used for logical batched and non-batched statistical analysis. Long produced by SPSS Inc., it was acquired by IBM in 2009. The current versions (2015) are officially named IBM SPSS Statistics. Companion products in the same family are used for survey authoring and deployment (IBM SPSS Data Collection), data mining (IBMSPSS Modeler), text analytics, and collaboration and deployment (batch and automated scoring services). SPSS is a widely used program for statistical analysis in social science. It is also used by market researchers, health researchers, survey companies, government, education researchers, marketing organizations, data miners and others. The original SPSS manual (Bent and Hull, 1970) has been described as one of "sociology's most influential books" for allowing ordinary researchers to do their own statistical analysis. In addition to statistical analysis, data management (case selection, file reshaping, creating derived data) and data documentation (a Metadata dictionary was stored in the data file) are features of the base software.

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO. CROPWAT 8.0 is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rain fed and irrigated conditions.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Demographic Characteristics of Irrigators

The discussed demographic characteristics of the irrigation user farming households were sex of the household heads, education, and marital status of the user households. The number of households who were irrigating their land using Ella and Bossa schemes were 220 and 175 respectively. Among them, male household heads covered 80% and 85% whereas female headed households covered only 20% and 15% in the Ella and Bossa schemes respectively. In reliable with this result, Tadesse *et al*, (2013) identified that male headed households were found to be more likely to implement irrigation technologies as compare to female-headed counterparts.

Each WUA participants obtains irrigation water on a rotating basis for a fixed period of seven or eight days per month. The technique for each user in the scheme is based on their field location relative to the main irrigation canal in both schemes. Farmers at the head and near the canal use water first as it is abstracted downstream. All farmers use the water in a monthly basis. In the cases that the user who did not get water within a monthly cycle are provided to use prior to others in the next schedule. All accessible water in the canal is fully used with irrigations carried out during the day and night, including holidays. Women household heads whose irrigation schedule cascades during the night and holidays either switch with their male neighbors or have male neighbors responsible to irrigate for them. However, those farmers scheduled to use the water during night time gets comparative advantages since as it is cooler, they get larger water discharge from the canal.

According to the data of table 4.1 below, the educational level of irrigators was found to be 58% from Ella and 38% from Bossa were able to read and write respectively as well as 28% from Ella and 48% from Bossa were attended elementary and above school grades. Hence, the result shown that majority of the farmers in the study areas able to read and write and above elementary level. This supports them as effort for the use or application of new technologies.

Ella SSI Scheme			Bossa SSI scheme		
Level of Education	**Frequency**	**Percentage (%)**	**Level of Education**	**Frequency**	**Percentage (%)**
Illiterate	10	14	Illiterate	9	14
Read and write	40	58	Read and write	24	38
Elementary and above	19	28	Elementary and above	31	48
Total	**69**	**100**		**64**	**100%**

Table 4.1. Shows the educational level of irrigators of the two schemes.

Source: Survey Result (2020).

In terms of marital status of the interviewed irrigators in both Ella and Bossa SSI schemes 68% and 73% were married, 26% and 23% of them were single and others 6% and 3% were divorced respectively. The data in table 4.2 shown as the majority of the irrigators were married and the divorced were few in number, which might be a worthy societal factor that increase the operation of small scale irrigation practices within the community.

Ella SSI Scheme			Bossa SSI Scheme		
Marital status	Frequency	Percentage (%)	Marital status	Frequency	Percentage (%)
Single	18	26%	Single	15	23%
Married	47	68%	Married	47	73%
Divorced	4	6%	Divorced	2	3%
Total	**69**	**100%**	**Total**	**64**	**100%**

Table 4.2. Shows the marital status of irrigators of the two schemes.

Source: Survey Result (2020).

4.2. The Current Status of Irrigation Schemes

4.2.1. Ella small scale irrigation scheme

Ella SSI scheme was constructed in 1986 and sponsored by World Vision Ethiopia (a non-governmental organization) and has been giving a service for 27 years operational period. The initial command area of Ella SSI scheme was 120ha, and now the command area of the scheme is expanded to 200ha. From the total command area, irrigable land covers 148ha. The land holding of beneficiaries ranges from 0.25ha to 1ha. The command area was classified in two blocks and in four clustered farm blocks. Additionally, the area was categorized into eight water user groups for operation and management purpose.

The main canal length is about 2.5km and constructed in lined masonry as well as earthen. Regardless of some breaking of canals by unlawful users, hydraulically the structure was under good condition. The secondary canal is totally earthen and has an average length of 3.6km, hydraulically the structure was under in a good situation, but it was covered by weeds and soils. Moreover, the tertiary canal is not well known and earthen type.

In the irrigation scheme flow control gates (metal sheets) were installed in the whole irrigation system at division boxes or turnouts, but almost all of them became out of function and some of them are looted.

According to the maintenance document from the Coordination of Zonal Water, Mine and Energy (2019), the scheme was categorized under moderately vulnerable to soil erosion. However, currently the area has been severely affected by erosion hazards. Due to erosion and sedimentation problems from the uphill of the watershed, the cultivated land frequently been covered by rubbles and gravels during rainy seasons and hampering farming activities. If the problem persists, it will sink the efficiency of farm land in the near future if it is not implemented the watershed management practices at the upstream of the scheme as soon as possible.

Even though the irrigation scheme was recommended for production of vegetables like (tomato, green pepper, cabbage, garlic and onion) by experts in their maintenance document (2019), farmers frequently used to cultivate main crops such as maize, green pepper, onion and cabbages through furrow type of irrigation method. The farmers are irrigating their farm through rigid rotational irrigation schedule and most of the time it takes eight days for one cycle/rotation.

4.2.1. Bossa small scale irrigation scheme

Bossa SSI was constructed with the capital sourced PASIDP from in 2000E.C and has been serving for 13 years. The designed command area was 100ha located in Bossa Wanche Kebele. However, currently 136ha is being irrigated during irrigation season in the Kebele. The land holding of beneficiaries ranges from 0.25ha to 1ha. For operation and management purpose the command area has three clustered farm blocks and seven water user groups.

The total length of the main canal is about 2.2km and which contains 400m lined masonry, and the remaining 1.8km is unlined earthen canal. Hydraulically the main canal is under good status but the earthen type canal and some flume exhibit seepages. However, most of the primary canals which are lined were broken, cracked and silted by weeds and soils. Although the irrigation scheme has no tertiary canals, in its place farmers uses field canals and directly from secondary canals. The secondary canal is again totally earthen and has an average length of 2.9km. Hydraulically the structure is in a good situation, but it was covered by again weeds and soils. Even though the irrigation scheme has no any water flow control gates at division boxes or turnouts, farmers use local control materials as an alternative (stone, soil, sacks filled with soil/sand). Since the slope of secondary canal is high, it creates a challenge in diverting the required amount of water from secondary canal through the local flow control materials.

Carrot, cabbage, garlic, onion, tomato and maize were the major crops recommended for production during design period. In addition to the above crops, currently farmers have been dominantly producing cereal crop like maize. Farmers produce following mono cropping system using irrigation.

Framers were not making use of the irrigation scheme during the early years immediately after the end of the construction, due to frustration that they conceived that the nutrient of their land will be depleted thoroughly if they use irrigation. Meanwhile the Wereda Agriculture and Natural Resources Development Office had strained to create wakefulness and influenced them to produce maize in 2001. But due to constraints like road inaccessibility, market linkage problems, and lack of agricultural inputs supply farmers did not became profitable. Currently, 136ha of the land is irrigated which is above the initial command area, though a lot of problems are existed in the scheme.

4.2.2. Determination of crop irrigation requirements

CROPWAT 8.0 model computed the crop water requirements based on equation (3.13) and it needs climatic data for ETo computation, crop characteristics data and soil description for the determination of crop and irrigation water requirements. Crop water requirements are defined as the depth of water needed to meet the water loss through evapotranspiration. It was determined for the main crops grown in both irrigation schemes based on equation (3.13). The main crops grown during the irrigation seasons have been identified for both schemes (table 3.1. and 3.2.).

Description of crop characteristics i.e., planting date and length of growing period (LGP) were collected from household survey results. Crop coefficient (Kc), maximum root depth (m), crop height, yield reduction factor (Ky) values were adopted from FAO (1989) Irrigation & Drainage paper 24 and 56, the detailed values in growth stage based are described in (Appendix table 11 and 12). The values of Kc in the growing period are represented by crop coefficient curve, the values varies in the growing period. The CROPWAT model required the three Kc coefficients (KC of initial, development and late stages). Furthermore, the allowable soil moisture depletion fraction for each crops at each growing stage were adopted from FAO (1989) Irrigation & Drainage paper 24 and 56.

Allowable moisture depletion fraction is a critical soil moisture level where the first drought stress occur affecting evapotranspiration and crop production. The fraction normally varies from 0.2-0.6 with the lower value being for sensitive crops with limited rooting systems. To estimate yield reductions associated with drought stress, yield response factor (Ky) was given as an input variable in the crop data option.

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

NSIR shown the total monthly irrigation demand of the irrigation schemes.

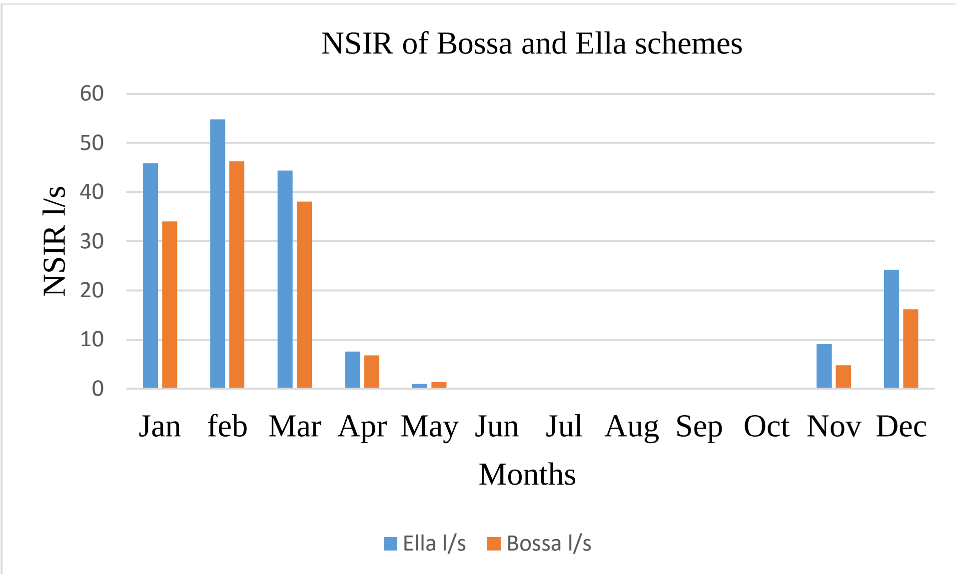

Figure 4.1. : Net scheme irrigation requirement at both schemes

	month											
	Jan	feb	Mar	Apr	May	Ju	Jul	Au	Se	Oc	Nov	Dec
Irr area %	100	100	100	73	22	0	0	0	0	0	51	78
Irr area	148	148	148	108.04	32.56	0	0	0	0	0	75.48	115.44
l/s/ha	0.31	0.37	0.3	0.07	0.03	0	0	0	0	0	0.12	0.21
l/s	45.88	54.76	44.4	7.5628	0.9768	0	0	0	0	0	9.0576	24.2424
m3	118921	141938	115085	19602.8	2531.87	0	0	0	0	0	23477.3	62836.3
Total												**484392 m^3**

Table 4.3: Ella scheme irrigation requirement

	month											
	Jan	feb	Mar	Apr	May	Ju	Jul	Au	Se	Oc	Nov	Dec
Irr area %	100	100	100	100	34	0	0	0	0	0	44	66
Irr area	136	136	136	136	46.24	0	0	0	0	0	59.84	89.76
l/s/ha	0.25	0.34	0.28	0.05	0.03	0	0	0	0	0	0.08	0.18
l/s	34	46.24	38.08	6.8	1.3872	0	0	0	0	0	4.7872	16.1568
m3	88128	119854	98703.4	17625.6	3595.62	0	0	0	0	0	12408.4	41878.4
Total												**382194 m^3**

Table4.4: Bossa scheme irrigation requirement

4.2.3. Crop Water Requirements of Major Irrigated Crops

To estimate crop water requirements of major irrigated crops in the area, inputs were collected from different sources. The climate and soil data were collected from Humbo woreda and wolaita zone water, mine and energy office. The CLIMWAT 2.0 software was used to obtain the climatic data of Sodo meteorological station which is the nearest to the projects area. The main purpose of crop water requirement estimation was to point out improvement opportunities and take actions through giving trainings for farmers regarding the amount of water required for each of the major irrigated crops grown in the area. CROPWAT 8 software was used to estimate the crop water requirements and determine irrigation scheduling.

Note: The soil textural class of the two schemes is red clay loamy (WWMEO).

CWR Maize $*\frac{Area\ of\ maize}{Total\ area}$ + CWR small vegetaion$*\frac{Area\ of\ small\ vegetation}{Total\ area}$ + CWR Tomato$*\frac{Area\ of\ Tomato}{Total\ area}$ = CWRCrop (Ella)

CWRCrop (Ella) = 616.9$*\frac{75}{148}$+ 680.3$\frac{40}{148}$+568.8$\frac{33}{148}$ = **623.31mm**

CWR Maize $*\frac{Area\ of\ maize}{Total\ area}$ + CWR potato$*\frac{Area\ of\ potato}{Total\ area}$ + CWR Cabbage$*\frac{Area\ of\ cabbage}{Total\ area}$ = CWR Crop (Bossa)

CWR Crop (Bossa) = 614.5$*\frac{60}{136}$+516$*\frac{30}{136}$+ 601.5$\frac{46}{136}$ = **588.15mm**

Where: CWR crop: is the water requirement of a crop calculated.

4.3. Irrigation performance evaluation

4.3.1. Water delivery performance indicators

4.3.1.1. Conveyance efficiency

Canal Section	Avg Depth(m)	Width (m)	Length (m)	Time Elapsed (sec)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	Ec (%)
ULMC1	0.15	0.7	30	45	0.105	0.667	0.070	81.82
ULMC2	0.15	0.7	30	55	0.105	0.545	0.057	
MUSC1	0.12	0.5	30	76	0.06	0.395	0.024	76.00
MUSC2	0.12	0.5	30	100	0.06	0.300	0.018	
LUSC1	0.11	0.4	30	103	0.044	0.291	0.013	65.19
LUSC2	0.11	0.4	30	158	0.044	0.190	0.008	

Table 4.5. Conveyance Efficiency of the Bossa Scheme

Note: Length from ULMC1- ULMC2= 2.2km, MUSC1- MUSC2= 1.5km and LUSC1-LUSC2= 1.4km

As water loss in the conveyance system is the major component of the overall irrigation system performance (discussed with farmers and irrigation experts), conveyance efficiency was determined at main and secondary canals (Table 4.5 and 4.6). The average conveyance efficiency of Bossa and Ella schemes during water delivery from source to field plot was 75.54% and 76.20% respectively (Table 4.7). These results are somewhat lower than the value of conveyance efficiency recommended for unlined canals, which was the recommended conveyance efficiency of lined and unlined canal less than 200m length are 95% and 90% respectively as (FOA, Annex I). This is owing to most of the canals in site were unlined and there was over topping in most of the canals due to inappropriate canal design and cracks. Additionally, there was frequent canal destruction raised from the peoples use the canal as a road and source of drinking water for their livestock and nobody pays irrigation fees for maintenance and operations. These accumulated causes aggravated water losses in the canal, which intern reduces the conveyance efficiency.

Canal section	**Avg Depth(m)**	**Width (m)**	**Length (m)**	**Time Elapsed(sec)**	**Area (m^2)**	**Velocity (m/s)**	**Discharge (m^3/s)**	**Ec (%)**
ULMC1	0.290	1.000	30.0	80.0	0.290	0.375	0.109	82.442
ULMC2	0.260	1.000	30.0	87.0	0.260	0.345	0.090	
MUSC1	0.170	0.790	30.0	100.0	0.134	0.300	0.040	73.813
MUSC2	0.150	0.760	30.0	115.0	0.114	0.261	0.030	
LUSC1	0.130	0.570	30.0	125.0	0.074	0.240	0.018	67.476
LUSC2	0.100	0.540	30.0	135.0	0.054	0.222	0.012	

Table 4.6. Conveyance Efficiency of the Ella Scheme

Note: Length from ULMC1- ULMC2= 2.5km, MUSC1- MUSC2= 2.5km and LUSC1- LUSC2= 1.1km

Values for irrigation water delivery				
Scheme name	**Irrigated area (ha)**	**Ec (%)**	**RWS**	**RIS**
Ella	148	76.25%	1.10	1.15
Bossa wanche	136	75.54%	0.96	0.90

Table 4.7: Water delivery performance indicators result (2012/13).

As it is clearly shown in Table 4.5, and 4.6 since the main canal was lined, and somewhere in the downstream side unlined. The conveyance efficiency of the main canals were relatively good which is 81.82% and 82.442% followed by middle secondary canal with 76% and 73.813% whereas the conveyance efficiency of the lower secondary canal was relatively poor with 65.19% and 67.476% for Bossa and Ella schemes respectively. The recommended conveyance efficiency of lined and unlined canal less than 200m length 95% and 90% respectively as (FOA, Annex I) so the value obtained was less than recommended value in both schemes that means both lined and unlined canals were seepage problem and canal cracks due to lack of maintenance.

4.3.1.2. Relative water supply (RWS)

Parameter	**Ella irrigation /seasonal**	**Bossa irrigation/ Seasonal**
Total water supply, m^3	994,571	767,756
Crop water demand, m^3	922,499	799,890
Effective rain	429,515	404,876
Irrigation supply, m^3	565,056	362,880
Irrigation demand, m^3	484,392	382,194
Crop type	(Maize, small vegetables, tomato...)	(Maize, potato, cabbage...)
Area developed (ha)	148	136
RWS	1.10	0.96
RIS	1.15	0.90

Table 4.8: Water supply indicators for Ella and Bossa irrigation schemes

Relative water supply (RWS) shows the ratio of total annual supply to the annual crop water demand and it measures the adequacy and seasonal timeline (Levine 1982 and Meinzen D., 1995, In Kloezen W.H & G.-R. Carlos, 1998). The total seasonal supply is the sum of irrigation water supplied to the field and total rainfall. As it is shown in table 4.8 both irrigation schemes the results for this indicator were 0.96 and 1.10 for Bossa and Ella irrigation schemes respectively. It shows that in Ella scheme there is excess water amount diverted from the river Likewise, in Bossa scheme the value is not shows there is water shortage but, for deficit irrigation system it is optimum amount of water diverted to meet the crop water demand.

4.3.1.3. Relative irrigation supplies (RIS)

The relative irrigation supply (RIS) indicates the ratio of irrigation supply to irrigation demand and it also assesses the degree of irrigation water stress/abundance in relation to irrigation demand. This indicator is used to assess the water use performance. In the table 4.8 above it can be observed that RIS value of Ella was higher than that of Bossa irrigation scheme. It is better to have RIS close to one than a higher or lower value (Molden *et al.*, 1998). These indicates that if their values would be equal to one then irrigation water supply was evaluated as optimal and if their values are less or greater than one it would mean under or over supply of water respectively. It has been observed that the RIS values for each scheme was 1.15 and 0.90 for Ella and Bossa schemes respectively and this value indicates that in Ella scheme there was over supply of water. The main reason for over supply at the irrigation scheme was the higher volume of water diverted without due consideration of demand and this was due to the absence of water pay system in the scheme. On the other hand, the distribution of the water was being carried out, to some amount, by users themselves.

In the case of Bossa scheme, the value indicates that there was a little bit water shortage delivered as compared to irrigation needed. However, this can possibly be managed through the application of deficit irrigation and able to maximize return on irrigation.

4.3.2. Physical performance indicators

4.3.2.1. Irrigation ratio and beneficiaries of targeted performance

Based on the results depicted in table 4.9 and 4.10 that even though both schemes were characterized as operational, they were not functioning at their full capacity. That means they were serving less than the planned command areas. As a result 75.6% and 74% of the total command area were cultivated during the irrigation period considered in Bossa and Ella irrigation schemes, respectively. This shows that, apart from inefficiencies that exist in cultivated command areas, 24.5% and 26% of the created irrigation potential was not being used in Bossa and Ella irrigation schemes, respectively.

Out of the 250 and 280 targeted beneficiaries of both Bossa and Ella schemes, 175 and 220 households accounting 70% and 78.6% targeted beneficiaries were being served respectively. The decrement of the beneficiaries was due to the fact that female household heads were unable to cultivate their lands during the irrigation season and the conflict over the tenure system.

Performance indicators	Parameters of performance	Sample counts	Performance level
Relative irrigated area	Actual irrigated area (ha)	136ha	75.6%
	Total planned command area(ha)	180ha	
Beneficiaries target performance	Actual beneficiaries	175HH	70%
	Target beneficiaries	250HH	
Sustainability of irrigated area	Currently irrigated area	136ha	172%
	Initially irrigated area	79ha	

Table 4.9. Bossa irrigation Scheme physical performance indicators result.

According to the field observations and discussions held with key informants, the reason for not functioning fully based on the above parameters were the existence of water theft, unequal distribution of water, lack of commitment, and lack of awareness on the irrigation system in both schemes. Unreliability of irrigation water supply due to the poorly functioning irrigation infrastructure and illegal utilization during night times (vandalism) were observed by most of the irrigation users. Unauthorized water users, seepage, canal blockage for washing clothes, and crowds of cattle drinking from the canals also added to water supply unreliability. In both irrigation schemes, many users complain for unfair distribution of irrigation water in their field. In irrigation project, for instance, unfair distribution of irrigation water is a serious problem due to illegal water users and a weak Water Users Association. In both schemes, the unfairness is attributed to the crooked Water Users Association and stake of headwater users.

Performance indicators	**Parameters of performance**	**Sample counts**	**Performance level**
Relative irrigated area	Actual irrigated area (ha)	148ha	74%
	Total planned command area (ha)	200ha	
Beneficiaries target performance	Actual beneficiaries	220HH	78.6%
	Target beneficiaries	280HH	
Sustainability of irrigated area	Currently irrigated area	148ha	108.2%
	Initially irrigated area	137ha	

Table 4.10. Ella irrigation Scheme physical performance indicators result.

4.3.2.2. Sustainability of irrigated area in ha/ha

The ratio of currently irrigated area to initially irrigated area was designed by (Bos, 1997). It is a useful indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator would mean abandonment of lands which were initially irrigated and, hence, indicate contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated area and would imply more sustainable irrigation. So, the values for sustainability of irrigate area for the two schemes are shown in tables 4.9 and 10 above. The value for sustainability of irrigation area for Ella Irrigation scheme was 1.082 which is 108.2% of area was currently under irrigation and the value was greater than one that means in comparison with initially irrigated area, currently irrigated area was increased by 8.02%. The result for sustainability irrigated area was 1.72 for Bossa irrigation, which indicates that 172% of the area was currently under irrigation compared to initially irrigated area it means a currently irrigated area of this scheme was increased by 72%.

In both irrigation schemes, the sustainability of irrigated area was increasing due to awareness of the increment of irrigators, expansion of suitable irrigation land, and initial command area which is planned was not considered the potential of land and water which are accessible to irrigate. Regardless of the fact that in both irrigation schemes flooding damages the farmers' field by loading stones on the field and affects the soil fertility, the farmers' utilization of land in irrigation season was increased by conserving their land from the frequently occurring floods. The flood erodes the fertile soil of the field and also it causes valleys that are not important for irrigation. Therefore, unless the flood is controlled, it leads in reduction of irrigation area after the long period of time.

4.3.3. Agricultural output indicators

Even though the variety of crops grown in an area varies from scheme to scheme, the production per unit hectare of land which is reliant on many influences differs among the scheme. Those aspects are disease infection, high cost of pesticides and insecticides, market failure, inaccessibility of good quality seeds with realistic price, fertility of the soil, and access to surface water and so on. Therefore, farmers prefer to cultivate crops that minimize the negative effects of these elements. The detailed analysis carried out with reference to each irrigation scheme that leads to assessment indicators were summarized in the following Tables 4.11 and 4.12.

No.	**Crop type**	**Area (ha)**	**Yield Qt/ha**	**Yield Qt**	**Price (Birr/Qt)**	**Revenue (Birr)**
1	Maize	75	32	2400	1200	2,880,000
2	Small vegetable	40	18	720	2000	1,440,000
3	Tomato	33	10	330	1400	462,000
4	**Total**					**4,782,000**

Table 4.11: Crop type and yield in Ella Irrigation scheme

No.	**Crop type**	**Area (ha)**	**Yield Qt/ha**	**Yield Qt**	**Price (Birr/Qt)**	**Revenue (Birr)**
1	Maize	60	30	1800	1100	1,980,000
2	Potato	30	45	1350	700	945,000
3	Cabbage	46	43	1978	650	1,285,700
4	**Total**					**4,210,700**

Table 4.12: Crop type and yield in Bossa Irrigation scheme

The production per unit of cultivated land in both irrigation schemes was different for the same crop. The production of maize, per hectare of land for Ella irrigation scheme was higher than that of Bossa irrigation and this variation was due to production constraints such as farmers have lack of knowledge in using inputs such as fertilizers, seeds, chemicals, water availability, soil fertility, land suitability, and using natural manure. Weed infestation and crop diseases were one of the production constraints that decrease crop yield, but the price per quintal (price/Qt) was the same, because the production in both schemes were sold in the same market (Tebela and Sodo towns). As it can be seen from Table 4.11 and 4.12, the total revenue for Ella and Bossa irrigation scheme was 4,782,000 birr and 4,210,700 birr respectively. The production difference was due to farming practice, soil fertility, crop varieties and adaptability and others. This can be improved by sharing farming practice, using fertilizer and planting crops adaptable to the farmers' field in order to increase the productivity of Bossa irrigation scheme.

For evaluation of agricultural indicators the main crops grown in both irrigation schemes and the total value of annual production were listed in table 4.11 and 4.12 including areal allocation of each crop for agricultural year of 2020 and were summarized in table 4.13 below. Four agricultural performance indicators for the two schemes were calculated by equation (3.7), equation (3.8), equation (3.9) and equation (3.10) for OPUIA, OPUCA, OPUIS and OPUWC, respectively and the results for those all parameter including performance indicators were also shown in table 4.13 below.

Parameters	Ella scheme	Bossa scheme
Irrigation supply	565,056	362,880
Crop water demand, m3	922,499.00	799,890.00
Nominal area, ha	200	180
Harvested area, ha	148	136
Value of seasonal production, birr	4,782,000	4,210,700
OPUIA in (Birr/ha)	32310.81	30961.03
OPUCA in (Birr/ha)	23910	23392.78
OPUIS in (Birr/m3)	8.46	11.60
OPUWC in (Birr/m3)	5.18	5.26

Table 4.13: Agricultural indicator for Ella irrigation and Bossa irrigation schemes.

4.3.3.1. Output per unit irrigated cropped (harvested) area (OPUIA) (Birr/ha)

The output per unit irrigated cropped area quantifies the total value of agricultural production per unit of area harvested. It shows the response of each cropped area on generating gross return and it was affected by other agricultural factors such as soil type and fertility, land suitability, crop variety, agricultural inputs and water availability. This indicator offers an indication about management practice in each scheme. As it can be shown in table 4.13 the results for this indicator was 32,310.81 birr/ha and 30,961.02 birr/ha for Ella and Bossa irrigation schemes respectively. Based on this information the return from Bossa irrigation scheme was less than that of Ella irrigation scheme. This was due to soil fertility, water availability, land suitability and crop variety as well as agricultural inputs have significant impact on land productivity (Malano *et al.*, 2004; Molden *et al.*, 1998). If the soil is productive and there is accessible water the output per unite irrigated cropped area are greater.

4.3.3.2. Output per unit command area (OPUCA) (Birr/ha)

This parameter directs the average returns of each design command area and it is different from scheme to scheme. The output per unit command of Ella irrigation scheme was higher than Bossa irrigation scheme. The irrigated area of Ella was 148ha and that of Bossa was 136ha respectively. As we have discussed in section 4.2.6, this indicator also works with water availability, soil type and soil fertility, land suitability and crop variety. Therefore, due to the aforementioned parameters, the production of crops is different from scheme to scheme and even it varies from farm lands in the same irrigation scheme and it holds trues in this study. With regard to Ella and Bossa irrigation schemes, the OPUCA was found to be 23,910 birr/ha and 23,392.78 birr/ha respectively. The result difference in each scheme was again due to water availability, soil fertility, land suitability and crop variety. When land is limiting relative to water, output per unit land may be more important. Where water is a limiting factor to production, output per unit water may be more important (Molden *et al.,* 1998).

4.3.3.3. Output per unit irrigation water supply (OPUIS) (Birr/m3)

This indicator shows the revenue of each volume of water in meter cube delivered to each irrigation schemes. It also articulates on how well the total annual diverted irrigation water from a source is useful. Irrigation water supply includes conveyance losses in canals. In areas where water is scarce, water management aims to increase the output per drop of irrigation water. As it obtained from the calculation in Ella scheme it was about 8.46 birr for one meter cube of irrigation water supply and for Bossa scheme it was 11.60 birr for the same meter cube of water supplied. This result shows that the output per unit irrigation water supply for Bossa irrigation scheme was higher than that of Ella irrigation scheme.

4.3.3.4. Output per unit water consumed (OPUWC) (Birr/m3)

This indicator tells on the output per unit annual volume of water consumed by actual evapotranspiration. Its value is highly dependent on climate. Moreover, less consumptive use coefficient due to water losses does not affect its value; as only the water consumptively used by the crops is considered (Molden *et al*., 1998). This parameter also shows the return on the water consumed in each irrigation scheme. The result of this output was 5.18birr/m^3 for Ella and 5.26birr/m^3 for Bossa irrigation scheme. In this result the value for Ella irrigation scheme was higher as compared to the Bossa irrigation scheme. This indicates that both schemes require a paramount attention in the consumed water so as to make efficient utilization of water from economic point of views.

4.3.4. Financial indicator

4.3.4.1.Gross return on investment

Due to lack of long term output production cost data in the irrigation schemes, only 2020/21 irrigation season gross value of production was used. Under this valuation, the cost of the distribution system was not well-known for both schemes as the system were built over a long period of time. As a calculation, the investment cost of a similar system nearby currently under construction was taken. This amounted to 9,500,000birr water delivery cost.

Based on equation 3.11, the values were computed and summarized in Table 4.11 and 4.12. The gross investment cost per hectare of each irrigation schemes were calculated for the actual irrigable area instead of the designed irrigable area. If we considered the designed irrigable area for the calculation of investment cost and the total productions were calculated from the current actual irrigable area, it would lead a wrong conclusion. The result is given on table 4.14.

Irrigation scheme	Irrigable area(ha)	Water delivery structures cost(birr)	Water delivery Structures cost birr/ha	SGVP (birr/ha)	GRI (%)
Ella	148	9,500,000	64189.2	23910	37.2
Bossa	136	9,500,000	69852.9	23392.77	33.5

Table 4.14: Investment cost of the irrigation systems

Where: GRI-gross return on investments.

Gross return on investment values of 37.2% and 33.5% were obtained from Ella and Bossa SSI schemes respectively. The results revealed that Ella had higher gross return on investment than Bossa. The possible reasons for high gross return on investment in Ella, were cultivation of high value crops and high irrigated land per irrigation season.

The reasons behind for the low GRI on Bossa's irrigation scheme were smaller irrigated area and lack of using fertilizer as compared to Ella. The study was consistent with results of other researcher in different areas. For example, 33% in Burkina Faso, 30% in India, 33% in Mexico and 34% in Sirilanka (Molden *et al.*, 1998). The gross return on investment cost values were poor, so that it requires improving the productivity of each scheme by applying recommended agronomic practices, using fertilizer and improved seeds.

In both schemes, particularly in Bossa SSI, needs to make use of the available irrigable area effectively with appropriate water management techniques and change the existing cropping pattern towards high value crops with implementing appropriate technologies.

4.4. Technical and operational problems of the irrigation schemes

According to the data identified by Robel (2005) and Girma (2006), 17 factors of head work and 19 planning, institution, social and operational nature problems were identified which contributes to the underperformance of irrigation schemes. Based on irrigators interviewed the occurrence of the factors and their weight of causing underperformance in the questionnaire were counted in the form of frequency distribution for each scheme.

4.4.1. Problems of Bossa small-scale irrigation scheme

Based on the results obtained during interviewing farmers as shown in table 4.15, damage on farmlands, main canal siltation, upstream flooding, downstream scouring, poor operation and maintenance (O & M), damage on weir proper were the first six major physical problems in the scheme identified.

No.	**Categories physical problems**	**Problems weightage**				**Total Sample Size**	**Weighted average**
		4	3	2	1		
1	Damage on farmlands and canals	47	11	5	1	64	24
2	Main canal siltation	39	18	7	0	64	23
3	poor operation and maintenance (O & M)	38	18	6	2	64	22
4	Downstream scouring	33	24	5	2	64	22
5	Damage on weir proper	30	8	24	2	64	20
6	Sedimentation of head work	29	28	7	0	64	22

Table 4.15 Major Head work problem Bossa scheme

Source: Survey result (2020).

Market problem, road problem, lack of community participation on construction, lack of project idea by community, weakness of WUA, and lack of skill and knowledge of DA are the major highly affecting socio economic problems in the scheme table 4.16.

No.	Planning, institution, social and operational problem	Problems weightage				Total Sample size	Weighted average
		4	3	2	1		
1	Market problem	43	14	6	1	64	23
2	Road problem	41	17	5	1	64	23
3	Lack of community participation on construction	22	32	10	0	64	21
4	Lack of project idea by community	32	22	10	0	64	22
5	Weakness of WUA	32	14	16	2	64	21
6	Lack of skill and knowledge of DA	36	13	6	9	64	21

Table 4.16 Major Socio economic problem Bossa scheme

Source: Survey result (2020).

4.4.2. Problems of Ella small-scale irrigation scheme.

As it can be seen from the table 4.17, the first top six head work problems that were causes for the underperformance are sedimentation of head work, main canal siltation, damage on farmlands, damage on the intake, upstream flooding, and downstream scouring.

No.	Categories physical problems	Problems weightage				Total Sample Size	Weighted average
		4	3	2	1		
1	Upstream flooding	38	14	17	0	69	23
2	Damage on farmlands and canals	38	13	18	0	69	23
3	Downstream scouring	37	15	17	0	69	23
4	Sedimentation of head work	38	12	19	0	69	23
5	Main canal siltation	38	12	19	0	69	23
6	Damage on the intake	38	12	18	1	69	23

Table 4.17 Major Head work problem Ella scheme

Source: Survey result (2020).

On the other hand, table 4.18 shows that the result of socio economic problems of the scheme. Based on the result obtained lack of credit, lack of timely supply of improved seeds and fertilizers, weaknesses of WUA, lack of storage, market problem, and road inaccessibility were the major socio economic problems of the scheme which contributes to the low efficiency of the scheme.

No.	Planning, institution, social and operational problem	Problems weightage				Total Sample size	Weighted average
		4	3	2	1		
1	Lack of credit	46	13	10	0	69	25
2	Market problem	35	22	12	0	69	23
3	Road problem	25	34	10	0	69	23
4	Lack of storage	20	40	9	0	69	22
5	Lack of supply of improved seeds and fertilizer timely	32	15	22	0	69	22
6	Weakness of WUA	31	16	22	0	69	22

Table 4.18 Major Socio economic problem Ella scheme
Source: Survey result (2020).

<u>**Note:**</u> problem weightage denoted as: 1= for no problem, 2= for low problem, 3= for medium problem, and 4= for high weight problem

The above tables 4.15, 4.16, 4.17, and 4.18 indicated that the type and weight of existing problems in diversion systems. Main canal siltation, sedimentation problem, upstream flooding, downstream scouring and damage on farmland and canals are the utmost stirring physical problems in each scheme. Similarly, as depicted on the above tables causes for the failure also attribute to issues such as poor operation and maintenance (O & M).

On the other hand, lack of credit, lack of supply of improved seeds, weakness of WUA, market problem and lack of community participation on construction were found to be the key socioeconomic problems in both schemes.

4.4.3. Sedimentation of headwork

Headwork sedimentation refers to the filling up of the structure with silt up to the crest level or, it is the overall submergence of the weir proper, wing walls and appurtenant structures such as gates due to settlement of sediment. Run off waters normally carry sediments load from their catchment and discharge it into the river. Constructing irrigation structures across the rivers disturbs the regime condition of the rivers and the reduction in flow velocity of raised crest of such structures settles some of the sediment load carried by the rivers to allow the passage of relatively silt free water to the downstream. In case of Ella scheme, siltation at head work is the major problem and factors that cause system insecure. In the study area this problem was provoked by clogging of under sluice (the annex figure 6 clarifies the case).

4.4.4. Main canal siltation

The difficult of main canal siltation is detected in both schemes considered for the purpose of this study. This problem is considered as the problem that may ascend from the improper site selection, sediment consideration and scheme operation. However, it is not quantified how much it affects due to siltation of the canal depth and the shape changed and as a result the designed velocity of canal has been different. In general main canal siltation could result because of one or combination of the silt load is observed to come either along with the river water (suspended and bed load) or as a runoff from upstream nearby catchment.

In both irrigation systems, turnouts were far apart and not evenly distributed in some areas. Therefore, irrigators break canals and extract water where there was no turnout. These illegal users cause a huge damage on canals and threatened safety and sustainability of distribution and conveyance canals. These criminals were not been held accountable through legal means.

4.4.5. Damage on farmlands and canals

This problem was expected to occur due to both either improper site selection or hydraulic design of components. It is observed damage on farm lands, especially canals is caused due to uncontrolled runoff from the watershed along the canals that initiated the canals bank erosion and consequently the bank collapse. In case of Ella scheme, farmlands near the river were damaged by the flood during rainy season every year. In spite of the farmers' effort at their farm level, the scheme irrigation land were decreasing it's soil fertility from year to year and loss of farmland top soil by the flood was found to be the main problem. During the field observation the following canal problems were observed.

4.4.5.1. Distorted canal bank

As observed during field observation, the main canal of both irrigation schemes specially in Bossa scheme was distorted due to uneven banks, fast water flowing and other animals dig holes in the canals and cattle climbing in and out the canal, reduced flow and frequent disruption of irrigation supply.

4.4.5.2. Poor water administration

In both irrigation schemes caused by scarce (distantly located) or non-functional structures like the division boxes and weak water users association. These resulted in abolishment and breakdown of structures, arbitrary and unsatisfactory water distribution, and ambiguity in water supply, excessive and arbitrarily off take of water by the individual farmer and shortage of water in middle and tail end.

4.4.5.3. Illegitimate off takes

These problems were produced by breaking the embankment of the canal observed in both of the irrigation schemes resulted in uncontrolled water off take and water loss, unequal water distribution, and rapid deterioration of the irrigation structure.

4.4.5.4. Canal barrier

In both Ella and Bossa irrigation schemes, canal vegetation and canal barrier of upstream water diversions to increase water inflow to their fields by increasing the water level (head). These activities reduced water flow through canals and unequal water distribution for farmers downstream.

4.4.5.5. Steep canal slopes

This problem was detected mainly in Bossa scheme main canals considering steep slope canal design due to technical limitations, introducing illegal diversions by the local farmers and advanced erosion of steep channels led to erosion of canal bottom and progressively digging–in of canal, erosion and land slide of side slopes and collapse of the embankment, continuous maintenance, frequent failure and disruption of water supply and loss of land. As observed during field visit the appropriate main canal of the scheme, the canal bed was eroded and the depth of the canal was increased and farmers were forced to waste their labor for frequent maintenance of canals.

4.4.6. Downstream Scouring

The problem was attributed to the improper structural selection for the site or hydraulic design. This problem was observed in both of the schemes. Mainly in case of Ella, downstream scouring problem was severe due to the fact that the site was located at the upper parts of the source river where tributaries meet. The observed problem on this scheme was caused by the improper hydraulic design which arises from poor knowledge of the energy dissipation and impact of sediment on the structure. The impervious floor is designed in all cases to reduce the surface flow action that causes scouring due to unbalanced pressure in the hydraulic jump trough. In the study area this problem occurs due to silting of stilling basin. These could have played significant role in controlling receding jumps and hence reducing erosive power of the flowing water (Chow, 1959). In the diversion schemes jam and scouring of the impervious floor was commonly observed. The prolonged occurrence of scrape and scouring of downstream portion of the structure may end up in the total collapse of the structures.

4.4.7. Upstream Flooding

This problem is endorsed to the improper site and structure selection, hydrology and sediment consideration, hydraulic design of weirs and components. As observed during field visits and interviewing irrigated farmers, this problem cause the way of river course modification, and forming large gully and destroy the right main canal of both schemes farmers. In case of Ella, the main canal was filled by sediments coming from flood whereas, in case of Bossa the upper catchment lands is eroded by the coming gullies.

4.4.8. Planning, institutional, social, and operational Problems

The planning in irrigation scheme shows a significant part in realizing the final goal of the scheme. The planning process in the progress of irrigation projects can be observed in the light of community will and participation. Therefore, good performance of the schemes is directly connected to the level of participation of community fellows in the planning procedure. According to table 4. 16 and 4.18, problems were indicated under this subsection out of which lack of credit and market problems were the highly frequent happening problems. The cause of these problems were lack of real planning that allows the farmers could get applicable credit and road accessibility so that they can run their farming system without disturbance.

The institutional uncertainty is one of the major limitations for the effective expansion and development of irrigated agriculture. In the implementation of irrigation schemes, various institutions are involved in the process of planning, design, implementation and operation & evaluation. However, in some of the schemes built by NGOs and GOs the expected level of participation of various institutions is not observed. Schemes of both Ella and Bossa can be cited as projects having no design and handing over documents. Preparation of proper design is the due responsibility of the implementing institution and the regional irrigation authority. The lack of proper design document also resulted in creating problem to proper completion and handing over of the schemes to concerned stakeholder institutions. It is clearly seen that the handing over problem largely results because of failure of concerned institutions to release their due responsibilities. The institutional problem is also revealed by the absence of follow up during the operational phase of the implemented schemes.

The planning and institutional problems can also be reflected in the proper operation and utilization of the implemented schemes. Establishing legal WUA is a task to be carried out during the planning process or right at the beginning of implementation. This important activity is carried out by the implementing institution and the respective cooperative promotion office. Failure to establish legally instituted strong WUA results problem of proper operation and maintenance of schemes and to keep water theft.

Operational problems can bring about inadequacies in the project as well as environmental imbalance and healthiness conditions in the surrounding of the scheme that may be affected due to lack of proper working of it. The most unsatisfying practice in the observed schemes was the occurrence of theft of irrigation structures frequently by the beneficiaries themselves. Theft of items which are either saleable or off use on the farm or in the home (such as extracting steel rods from reinforced concrete structures) is also very common. For instance, in gates of main canal of both irrigation schemes especially in Bossa scheme have been broken as a result of such crazy vandalism. The issue of downstream water rights is something that should be discussed in detail during the feasibility study and failure of doing these results in creating operation and utilization problems discussed above.

The users of irrigation schemes in the area are characterized by low revenue condition at household level. Small scale irrigation can lead to availability of food at household level through increased productivity, stable production and hence increases income leading to alleviation of economic problems at household level. It also appears that development of small scale irrigation schemes helps the country attain food self-sufficiency at national level. Ethiopia's national target is to achieve food security both at national and household levels.

In general, the detected problems are not only the argued ones; many other problems were seen in both Ella and Bossa schemes during the field observation and all observed problems were presented with their respective weight in the annex tables 13, 14, 15 and 16.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this thesis, we have evaluated the problems for two small scale irrigation schemes. Ella and Bossa small scale irrigation schemes performance and current status were assessed by using water delivery; physical, financial and agricultural performance indicators as well as the factors that cause underperformance of the schemes were identified. Assessing the performance of small scale irrigation schemes is significant to identify the status, sustainability and production of the irrigation schemes. The performance indicators used in this research were: water delivery indicators (Relative water supply (RWS), relative irrigation supply (RIS) and conveyance efficiency), physical sustainability indicators (irrigation ratio, beneficiaries of targeted performance and sustainability of irrigated area) and agricultural indicators (Output per unit irrigated cropped (harvested) area (OPUIA), Output per unit command area (OPUCA), output per unit irrigation water supply (OPUIS), Output per unit water consumed (OPUWC). The questionnaire was developed to collect the perception of water users to identify problems which causes the underperformance of the schemes.

In terms of water delivery indicators both RWS and RIS that were greater than one which shows excess supply of water in Ella schemes but in case of Bossa those parameters are less than one which shows there is deficiency of water. The result of conveyance efficiency shows 24.46% and 23.75% amount of water was lost to reach the command area from the source for Bossa and Ella schemes, respectively.

The results for physical sustainability indicators: the irrigation ratio shows the degree of utilization of available irrigable area. Hence, 24.4% and 26% of irrigable land has not been irrigated for Bossa and Ella irrigation, respectively. Sustainability of irrigation shows the contraction or expansion of the irrigation regarding to nominal area initially developed. The values for this indicator for Bossa and Ella irrigation were greater than one and the area for the both irrigation schemes were expanding. Another physical sustainability parameter is beneficiary target performance. The result of this indicator shows that the water users currently are lower than that of water users initially planned.

The result for agricultural output indicators OPUIA, OPUCA, OPUIS, OPUWC show the predation per cropped area and output per volume of water supply. In general for these indicators the values of OPUIA, and OPUCA were lower and the value of OPUIS and OPUWC were higher for Bossa irrigation scheme than Ella irrigation scheme.

To identify the causes of underperformance of the schemes: damage on farmlands, main canal siltation, upstream flooding, downstream scouring, poor operation and maintenance (O & M), and damage on weir proper are the first six major physical problems in Bossa scheme. In addition, market problem, road problem, lack of community participation on construction, lack of project idea by community, weakness of WUA, lack of experts (DA) are the major highly affecting socio economic problems in the same scheme.

On the other hand, in Ella scheme Sedimentation of head work, main canal siltation, damage on farmlands, damage on the intake, upstream flooding and downstream scouring are the major physical problems that causes for the underperformance. Similarly, lack of credit, lack of supply of improved seeds and fertilizers timely, weakness of WUA, and road problem are the major socio economic problems which contributes to the low efficiency of the scheme.

5.2. Recommendations

Based on the results of this study, the following recommendations were given to improve and reduce the problems of small scale irrigation schemes of the study area.

- The evaluation of the performance of irrigation systems will help to now the current status of the systems. Therefore for the improvement of the irrigation system management and the irrigation practice frequent performance evaluation is vital.
- Prior to developing an irrigation projects for farmers, the capability of farmers whether they manage it or not must be considered. And monitoring should be practiced than totally left the operation for the farmers.
- The output from cultivable area of Bossa irrigation scheme was low. So it should improve its production by experience sharing from Ella irrigation scheme. Therefore farmers and development agents of these systems should share experience by visiting their sites one another. And this would be best if the government after identifying the weaknesses and strengths of each site by conducting subsequent performance evaluation assists it.
- The revenue from the water supplied in each scheme is varying and it was low in Bossa irrigation scheme. Therefore, to maximize the return from each drop of water a great effort should be carried out particularly in Bossa irrigation scheme. This may be improved by implementing reasonable irrigation water fee than giving them for free.

- The design of any small scale irrigation project should consider different aspects of social, cultural and economic aspects of the beneficiaries. For example, an irrigation project which didn’t consider cattle troughs around the project and culverts for the pass of the cattle, will led to the damage of the canals.
- Implementation of water shade management practices on the upper catchment was the policy recommendations to alleviate the problems identified and improve the current status of the schemes.

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ANNEXES

Annex A: Cropwat data

Climatic condition of the study area by using Sodo station which is the nearest to both schemes.

Bossa scheme

Crop Water Requirements

ETo station: Bossa | Crop: MAIZE (Grain)

Rain station: SODO | Planting date: 15/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.70	1.39	8.3	6.5	3.0
Nov	3	Init	0.70	1.29	12.9	9.9	3.0
Dec	1	Init	0.70	1.19	11.9	9.4	2.5
Dec	2	Deve	0.72	1.13	11.3	7.6	3.8
Dec	3	Deve	0.83	1.42	15.6	8.1	7.5
Jan	1	Deve	0.95	1.75	17.5	8.7	8.8
Jan	2	Deve	1.06	2.11	21.1	9.0	12.1
Jan	3	Mid	1.14	2.55	28.1	10.0	18.0
Feb	1	Mid	1.15	2.84	28.4	10.3	18.1
Feb	2	Mid	1.15	3.13	31.3	10.8	20.5
Feb	3	Mid	1.15	3.56	28.4	15.5	13.0
Mar	1	Late	1.14	4.04	40.4	20.5	19.9
Mar	2	Late	1.12	4.42	44.2	24.7	19.4
Mar	3	Late	1.10	4.31	47.4	29.0	18.4
Apr	1	Late	1.07	4.17	33.4	27.4	0.0
					380.4	**207.5**	**168.0**

Appendix table 1: Bossa scheme maize crop water requirement

Crop irrigation schedule

ETo station: Bossa | Crop: MAIZE (Grain) | Planting date: 15/11 | Yield red. 0.0 %

Rain station: SODO | Soil: | Harvest date: 08/04

Table format: (•) Irrigation schedule ( ) Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
21 Feb	99	Mid	0.0	1.00	100	56	100.1	0.0	0.0	143.1	0.17
8 Apr	End	End	0.0	1.00	0	24					

Totals

Total gross irrigation	143.1	mm	Total rainfall	239.5	mm
Total net irrigation	100.1	mm	Effective rainfall	232.0	mm
Total irrigation losses	0.0	mm	Total rain loss	7.5	mm
Actual water use by crop	376.2	mm	Moist deficit at harvest	44.1	mm
Potential water use by crop	376.2	mm	Actual irrigation requirement	144.2	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	96.9	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.40	0.40	1.30	0.50	1.25	
Yield reduction	0.0	0.0	0.0	0.0		%
Cumulative yield reduction	0.0	0.0	0.0	0.0	0.0	%

Appendix table 2: Bossa scheme maize crop irrigation schedule

Crop Water Requirements

ETo station: Bossa | Crop: POTATO

Rain station: SODO | Planting date: 01/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.50	1.08	10.8	18.6	0.0
Nov	2	Init	0.50	0.99	9.9	10.8	0.0
Nov	3	Deve	0.53	0.97	9.7	9.9	0.0
Dec	1	Deve	0.69	1.18	11.8	9.4	2.4
Dec	2	Deve	0.88	1.38	13.8	7.6	6.2
Dec	3	Mid	1.07	1.82	20.1	8.1	12.0
Jan	1	Mid	1.15	2.11	21.1	8.7	12.4
Jan	2	Mid	1.15	2.27	22.7	9.0	13.7
Jan	3	Mid	1.15	2.55	28.1	10.0	18.1
Feb	1	Mid	1.15	2.84	28.4	10.3	18.1
Feb	2	Late	1.14	3.11	31.1	10.8	20.2
Feb	3	Late	1.02	3.16	25.3	15.5	9.8
Mar	1	Late	0.84	2.98	29.8	20.5	9.3
Mar	2	Late	0.70	2.75	13.7	12.4	1.4
					276.3	161.6	123.5

Appendix table 3: Bossa scheme potato crop water requirement

Crop irrigation schedule

ETo station: Bossa | Crop: POTATO | Planting date: 01/11 | Yield red.: 0.0 %

Rain station: SODO | Soil: | Harvest date: 15/03

Table format: (•) Irrigation schedule ( ) Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
20 Feb	112	End	0.0	1.00	100	58	103.7	0.0	0.0	148.1	0.15
15 Mar	End	End	0.0	1.00	100	8					

Totals

Total gross irrigation	148.1	mm	Total rainfall	173.4	mm
Total net irrigation	103.7	mm	Effective rainfall	155.8	mm
Total irrigation losses	0.0	mm	Total rain loss	17.7	mm
Actual water use by crop	273.6	mm	Moist deficit at harvest	14.2	mm
Potential water use by crop	273.6	mm	Actual irrigation requirement	117.8	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	89.8	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.40	0.40	1.30	0.50	1.25	
Yield reduction	0.0	0.0	0.0	0.0		%
Cumulative yield reduction	0.0	0.0	0.0	0.0	0.0	%

Appendix table 4: Bossa scheme potato crop irrigation schedule

Crop Water Requirements

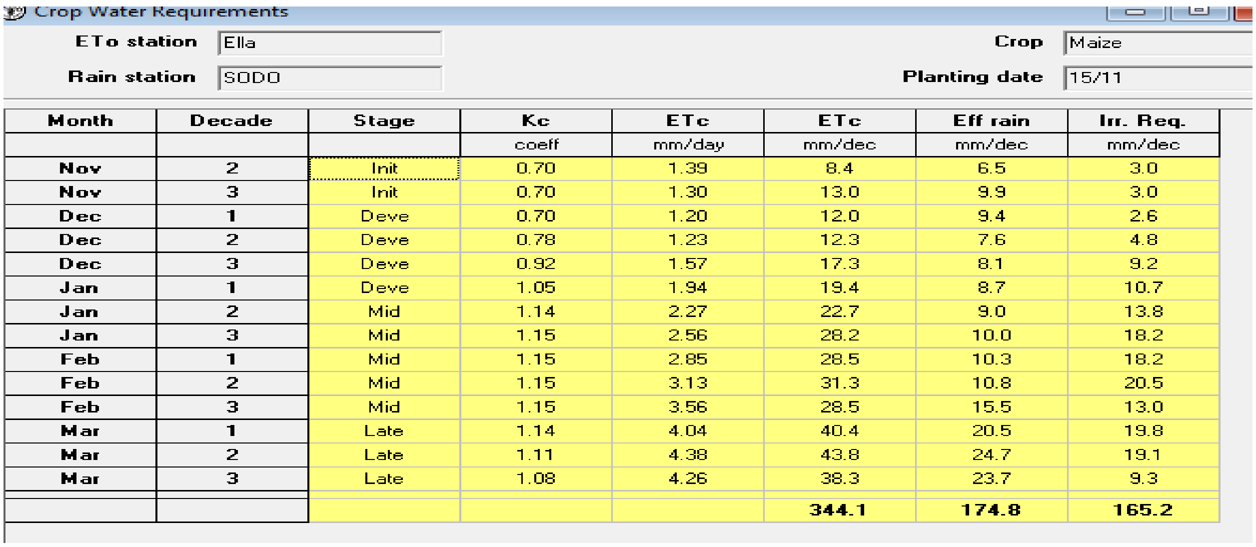
ETo station: Bossa | Crop: CABBAGE Crucifers

Rain station: SODO | Planting date: 01/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.70	1.52	15.2	18.6	0.0
Nov	2	Init	0.70	1.39	13.9	10.8	3.1
Nov	3	Init	0.70	1.29	12.9	9.9	3.0
Dec	1	Init	0.70	1.19	11.9	9.4	2.5
Dec	2	Deve	0.73	1.15	11.5	7.6	3.9
Dec	3	Deve	0.80	1.36	14.9	8.1	6.8
Jan	1	Deve	0.86	1.58	15.8	8.7	7.1
Jan	2	Deve	0.92	1.82	18.2	9.0	9.2
Jan	3	Deve	0.98	2.18	24.0	10.0	14.0
Feb	1	Mid	1.04	2.58	25.8	10.3	15.5
Feb	2	Mid	1.06	2.88	28.8	10.8	18.0
Feb	3	Mid	1.06	3.27	26.2	15.5	10.7
Mar	1	Mid	1.06	3.74	37.4	20.5	16.8
Mar	2	Mid	1.06	4.16	41.6	24.7	16.9
Mar	3	Late	1.06	4.15	45.6	29.0	16.7
Apr	1	Late	1.01	3.92	39.2	34.3	5.0
Apr	2	Late	0.96	3.75	15.0	15.6	0.0
					398.0	252.8	149.2

Appendix table 5: Bossa scheme cabbage crop water requirement

Ella scheme



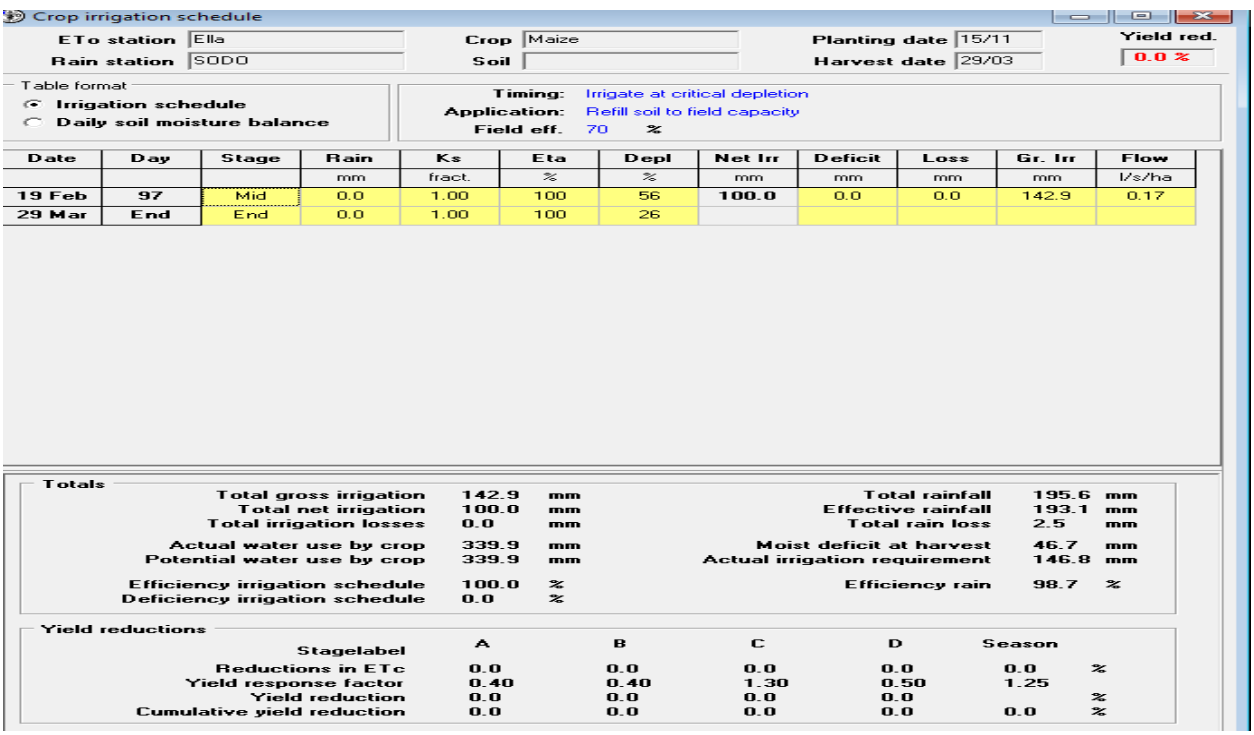
Crop Water Requirements

ETo station: Ella | Crop: Maize

Rain station: SODO | Planting date: 15/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.70	1.39	8.4	6.5	3.0
Nov	3	Init	0.70	1.30	13.0	9.9	3.0
Dec	1	Deve	0.70	1.20	12.0	9.4	2.6
Dec	2	Deve	0.78	1.23	12.3	7.6	4.8
Dec	3	Deve	0.92	1.57	17.3	8.1	9.2
Jan	1	Deve	1.05	1.94	19.4	8.7	10.7
Jan	2	Mid	1.14	2.27	22.7	9.0	13.8
Jan	3	Mid	1.15	2.56	28.2	10.0	18.2
Feb	1	Mid	1.15	2.85	28.5	10.3	18.2
Feb	2	Mid	1.15	3.13	31.3	10.8	20.5
Feb	3	Mid	1.15	3.56	28.5	15.5	13.0
Mar	1	Late	1.14	4.04	40.4	20.5	19.8
Mar	2	Late	1.11	4.38	43.8	24.7	19.1
Mar	3	Late	1.08	4.26	38.3	23.7	9.3
					344.1	174.8	165.2

Appendix table 6: Ella scheme maize crop water requirement



Crop irrigation schedule

ETo station: Ella | Crop: Maize | Planting date: 15/11 | Yield red.: 0.0 %

Rain station: SODO | Soil: | Harvest date: 29/03

Table format: (•) Irrigation schedule ( ) Daily soil moisture balance

Timing: Irrigate at critical depletion

Application: Refill soil to field capacity

Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
19 Feb	97	Mid	0.0	1.00	100	56	100.0	0.0	0.0	142.9	0.17
29 Mar	End	End	0.0	1.00	100	26					

Totals

Total gross irrigation	142.9	mm	Total rainfall	195.6	mm
Total net irrigation	100.0	mm	Effective rainfall	193.1	mm
Total irrigation losses	0.0	mm	Total rain loss	2.5	mm
Actual water use by crop	339.9	mm	Moist deficit at harvest	46.7	mm
Potential water use by crop	339.9	mm	Actual irrigation requirement	146.8	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	98.7	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.40	0.40	1.30	0.50	1.25	
Yield reduction	0.0	0.0	0.0	0.0		%
Cumulative yield reduction	0.0	0.0	0.0	0.0	0.0	%

Appendix table 7: Ella scheme maize crop irrigation schedule

Crop irrigation schedule

ETo station: Ella | Crop: Tomato | Planting date: 25/11 | Yield red.: 0.0 %

Rain station: SODO | Soil: | Harvest date: 25/04

Table format: (•) Irrigation schedule ( ) Daily soil moisture balance

Timing: Irrigate at critical depletion

Application: Refill soil to field capacity

Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
2 Mar	98	Mid	0.0	1.00	100	57	102.8	0.0	0.0	146.8	0.17
25 Apr	End	End	0.0	1.00	100	13					

Totals

Total gross irrigation	146.8	mm	Total rainfall	306.5	mm
Total net irrigation	102.8	mm	Effective rainfall	292.2	mm
Total irrigation losses	0.0	mm	Total rain loss	14.3	mm
Actual water use by crop	417.6	mm	Moist deficit at harvest	22.6	mm
Potential water use by crop	417.6	mm	Actual irrigation requirement	125.4	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	95.3	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.40	0.40	1.30	0.50	1.25	
Yield reduction	0.0	0.0	0.0	0.0		%
Cumulative yield reduction	0.0	0.0	0.0	0.0	0.0	%

Appendix table 8: Ella scheme Tomato crop irrigation schedule

Crop Water Requirements

ETo station: Ella | Crop: Tomato

Rain station: SODO | Planting date: 25/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	3	Init	0.60	1.11	6.7	6.0	1.7
Dec	1	Init	0.60	1.03	10.3	9.4	0.9
Dec	2	Deve	0.60	0.95	9.5	7.6	1.9
Dec	3	Deve	0.70	1.19	13.1	8.1	5.0
Jan	1	Deve	0.84	1.56	15.6	8.7	6.8
Jan	2	Deve	0.98	1.95	19.5	9.0	10.5
Jan	3	Mid	1.12	2.50	27.6	10.0	17.5
Feb	1	Mid	1.16	2.87	28.7	10.3	18.4
Feb	2	Mid	1.16	3.16	31.6	10.8	20.7
Feb	3	Mid	1.16	3.59	28.7	15.5	13.2
Mar	1	Mid	1.16	4.09	40.9	20.5	20.4
Mar	2	Mid	1.16	4.56	45.6	24.7	20.9
Mar	3	Late	1.15	4.53	49.8	29.0	20.9
Apr	1	Late	1.06	4.11	41.1	34.3	6.8
Apr	2	Late	0.92	3.61	36.1	39.0	0.0
Apr	3	Late	0.83	3.22	16.1	19.5	0.0
					420.8	**262.4**	**165.7**

Appendix table 9: Ella scheme Tomato crop water requirement

Crop irrigation schedule

ETo station: Ella | Crop: Small vegetable | Planting date: 25/11 | Yield red.: 0.0 %

Rain station: SODO | Soil: | Harvest date: 18/05

Table format
- (•) Irrigation schedule
- ( ) Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
2 Mar	98	Mid	0.0	1.00	100	56	101.7	0.0	0.0	145.2	0.17
18 May	End	End	0.0	1.00	0	2					

Totals

Total gross irrigation	145.2	mm	Total rainfall	436.5	mm
Total net irrigation	101.7	mm	Effective rainfall	396.6	mm
Total irrigation losses	0.0	mm	Total rain loss	39.9	mm
Actual water use by crop	502.1	mm	Moist deficit at harvest	3.8	mm
Potential water use by crop	502.1	mm	Actual irrigation requirement	105.5	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	90.9	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.40	0.40	1.30	0.50	1.25	
Yield reduction	0.0	0.0	0.0	0.0		%
Cumulative yield reduction	0.0	0.0	0.0	0.0	0.0	%

Appendix table 10: Ella scheme small vegetable crop irrigation schedule

Crop Water Requirements

ETo station: Ella | Crop: Small vegetable

Rain station: SODO | Planting date: 25/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	3	Init	0.70	1.30	7.8	6.0	2.8
Dec	1	Init	0.70	1.20	12.0	9.4	2.6
Dec	2	Deve	0.72	1.13	11.3	7.6	3.8
Dec	3	Deve	0.82	1.41	15.5	8.1	7.4
Jan	1	Deve	0.93	1.72	17.2	8.7	8.4
Jan	2	Mid	1.03	2.04	20.4	9.0	11.4
Jan	3	Mid	1.05	2.36	25.9	10.0	15.9
Feb	1	Mid	1.05	2.62	26.2	10.3	15.9
Feb	2	Mid	1.05	2.88	28.8	10.8	18.0
Feb	3	Mid	1.05	3.27	26.2	15.5	10.7
Mar	1	Mid	1.05	3.73	37.3	20.5	16.8
Mar	2	Mid	1.05	4.16	41.6	24.7	16.8
Mar	3	Mid	1.05	4.14	45.6	29.0	16.6
Apr	1	Late	1.05	4.09	40.9	34.3	6.7
Apr	2	Late	1.04	4.06	40.6	39.0	1.6
Apr	3	Late	1.02	3.97	39.7	39.0	0.6
May	1	Late	1.00	3.87	38.7	38.7	0.0
May	2	Late	0.98	3.79	30.3	31.5	0.0
					505.8	352.2	155.8

Appendix table 11: Ella scheme small vegetable crop water requirement

			Growth stages				
No.	Crop		I	D	M	L	Total
1	Tomatto	Kc	0.45		1.15	0.8	
		LGC	20	25	45	20	110
		Z(m)	0.25			1.1	
		P	0.3		0.4	0.5	
		Ky	0.45	1.1	0.8	0.4	1.08
		Hm(m)					0.6
2	Small vegetable	Kc	0.7		1.05	0.75	
		LGC	15	30	50	15	110
		Z(m)	0.2				0.6
		P	0.2		0.3	0.3	
		Ky	0.45	1	0.8	0.3	1.1
		Hm(m)					0.4
3	Maize	Kc	0.4		1.15	0.75	
		LGC	15	35	35	15	100
		Z(m)	0.3				0.8
		P	0.3		0.3	0.7	
		Ky	0.4	1	1.3	0.5	1.25
		Hm(m)					2

Appendix table 11: Crops characteristic data for Ella SSI scheme

			Growth stages				
No.	Crop		I	D	M	L	Total
1	Cabbage	Kc	0.7		1.05	0.95	
		LGC	20	20	40	20	110
		Z(m)	0.15			0.6	
		P	0.4		0.4	0.4	
		Ky	0.2	0.8	0.7	0.6	0.95
		Hm(m)					0.4
2	Potato	Kc	0.5		1.15	0.5	
		LGC	20	30	40	20	110
		Z(m)	0.3			1	
		P	0.4		0.4	0.7	
		Ky	0.4	0.8	1	0.7	
		Hm(m)					0.6
3	Maize	Kc	0.4		1.15	0.75	
		LGC	15	35	35	15	100
		Z(m)	0.3				0.8
		P	0.3		0.3	0.7	
		Ky	0.4	1	1.3	0.5	1.25
		Hm(m)					2

Appendix table 12: Crops characteristic data for Ella SSI scheme

Annex B: Questionnaire

HAWASA UNIVERSITY

INSTITUITE OF TECHNOLOGY

DEPARTMENT OF WATER RESOURCE AND IRRIGATION ENGINEERING

Questionnaire developed to evaluate problems of small scale irrigation of Target Farmers and Groups

The main objective of this questionnaire is to collect all relevant information (primary data) from the study area for the partial fulfillment of MSc Degree in water resource engineering and management study. The data will be utilized only for academic purpose. That is, to conduct master thesis research on the evaluation of problems of small scale irrigation schemes in Ethiopia, with special reference to SNNPR, Humbo woreda.

Dear respondent! Your information is very much valuable to achieve the desired goal of this study. Thus, you are kindly requested to give answer freely and openly. Any information you give is to be kept confidential!

Thank you very much for your sincerely cooperation!

TinsaeDalga

Questions for household heads

Part A. General: household information

1. Address: Kebele ________Gote (mender) ________________
2. Sex ____ Age _____
3. Educational level: Illiterate ☐ Read & write ☐ 1-8 ☐ 9-12 ☐ Above 12 ☐
4. House hold size: Male _____ Female _______ Total _______.
5. Marital status: ☐ Single ☐ Married ☐ Divorced ☐ Other______

Part B. Evaluation of problems about SSI schemes

The data of table 1 and 2 used for the evaluation of the problem of SSI schemes. Each problem is given a weight of severity for occurring from high to low and 'No'' for not occurring in each irrigation schemes.

No.	**physical problems categorizes**	**Problems weightage**			
		High	**Medium**	**Low**	**No**
1.	Damage on farmlands and canals	47	11	5	1
2.	Main canal siltation	39	18	7	0
3.	Upstream flooding	38	18	6	2
4.	Downstream scouring	33	24	5	2
5.	Sedimentation of head work	29	28	7	0
6.	Poor operation and maintenance (0 & M)	24	33	7	0
7.	Poor land levelling , Poor maintenance or lack of field channels	33	16	12	3

8.	Salinity and waterlogging	30	15	16	3
9.	Inadequate structural development	23	24	16	1
10.	Damage on Weir proper	30	8	24	2
11.	Clogging on the under sluice	29	16	5	14
12.	Damage on retaining wall	15	28	19	2
13.	Damage on the intake	22	15	23	4
14.	Damage on scouring sluice	20	24	6	14
15.	Damage on the downstream cutoff	12	32	7	13
16.	Damage on downstream apron	15	12	23	14
17.	Change in river course	0	2	39	23

Appendix Table 13. Problems on the head work of the Bossa small scale irrigation scheme

Source: survey result, 2020

No.	**Planning ,institution, social and operational problem**	**Weightage of problems**			
		High	**Medium**	**Low**	**No**
1	Market problem	43	14	6	1
2	Road problem	41	17	5	1
3	Lack of project idea by community	32	22	10	0
4	Lack of credit	22	32	10	0
5	Lack of community participation on construction	36	13	6	9
6	Lack of WUA established	32	14	16	2
7	Presence of crop disease	21	34	8	1
8	Inequitable distribution of agricultural production and	18	40	5	1

	water				
9	Lack of land redistribution	18	34	11	1
10	Lack of experts (DA)	26	23	5	10
11	Conflict over irrigation water utilization	18	30	13	3
12	Water shortage	14	36	12	2
13	Lack of selective crop production system	24	17	16	7
14	Lack of supply of improved seeds and fertilizer timely	14	35	10	5
15	Lack of storage	25	15	16	8
16	Inequity and conflict over agricultural production and water distribution	11	22	28	3
17	Area developed under planned	12	27	6	19
18	Lack of benefit from the system	23	14	2	1
19	Continuity of irrigated areas	11	16	5	32

Appendix Table 14: Socio economic problems on Bossa small scale irrigation scheme.

Source: survey result, 2020

No.	**physical problems categorizes**	**Problems weightage**				
		High	**Medium**	**Low**	**No**	**Total**
1	Upstream flooding	38	14	17	0	69
2	Damage on farmlands and canals	38	13	18	0	69
3	Downstream scouring	37	15	17	0	69
4	Sedimentation of head work	38	12	19	0	69
5	Main canal siltation	38	12	19	0	69

6	Damage on the intake	38	12	18	1	69
7	Damage on scouring sluice	35	15	19	0	69
8	Poor operation and maintenance (0 & M)	33	16	19	1	69
9	Damage on retaining wall	28	23	18	0	69
10	Damage on downstream apron	26	24	19	0	69
11	Damage on the downstream cutoff	21	31	17	0	69
12	Damage on Weir proper	15	37	17	0	69
13	Poor land levelling , Poor maintenance or lack of field channels	16	35	18	0	69
14	Inadequate structural development	18	31	20	0	69
15	Salinity and waterlogging	18	31	20	0	69
16	Clogging on the under sluice	16	33	20	0	69
17	Change in river course	16	18	35	0	69

Appendix Table 15. Problems on the head work of the Ella small scale irrigation scheme

Source: survey result, 2020

No.	**Planning ,institution, social and operational problem**	**Weightage of problems**			
		High	**Medium**	**Low**	**No**
1	Lack of credit	46	13	10	0
2	Market problem	35	22	12	0
3	Road problem	25	34	10	0
4	Lack of storage	20	40	9	0
5	Lack of supply of improved seeds and fertilizer timely	32	15	22	0
6	Lack of WUA established	31	16	22	0

7	Conflict over irrigation water utilization	30	18	20	1
8	Continuity of irrigated areas	16	44	9	0
9	Lack of community participation on construction	30	16	23	0
10	Water shortage	15	44	10	0
11	Inequitable distribution of agricultural production and water	24	26	19	0
12	Lack of selective crop production system	13	47	9	0
13	Presence of crop disease	14	45	10	0
14	Lack of project idea by community	13	45	11	0
15	Lack of experts (DA)	28	15	26	0
16	Inequity and conflict over agricultural production and water distribution	24	23	22	0
17	Area developed under planned	17	33	19	0
18	Lack of land redistribution	17	32	20	0
19	Lack of benefit from the system	46	13	10	0

Appendix Table 16. Socio economic problems on the Ella small scale irrigation scheme.

Source: survey result, 2020

II) Checklist for Woreda Irrigation Office

A. Original construction

1. When was the system constructed?

2. Who initiated and organized the initial construction?

3. How were the intake, layout of canals, and command area selected and designed? Who was responsible for that work (name, where from)?

4. Estimated silt load (high, medium, low)?

5. Water quality for irrigation (good, poor)? Why?

B. How often is the diversion damaged? One or two times each year? Every few years?

C. Soil types

What are the soil types and how do they vary throughout the system?

D. Physical constraints to increasing the irrigated area

1. What is the current status of irrigation schemes
2. What are the limitations to increasing the irrigated area?

a. No more land that can be irrigated?

b. Source of water limited?

c. Water delivery problems due to:

1) Inadequate diversion structure

2) Siltation

3) Seepage from the canal

4) Landslides

5) Canal size

6) Uncontrolled stream crossings

E. Other uses of water and WUA establishment?

Are structures provided or special provisions made using the system for purposes other than crop production?

Such as bathing, washing clothes, watering animals, running a turbine or water wheel?

F. Distribution system

1. What physical control devices are used?

a. Temporary earth diversion?

b. Permanent gates, keys (proportioning weirs)?

If keys are used, sketch the branches and measure the respective key notches.

c. When are these controls in operation?

d. Who is responsible to construct them?

e. Who maintains them?

G. Conflict resolution

1. What are sources of conflict other than water stealing? Give examples of specific conflicts, e.g. Uncontrolled grazing, refusing to work when they are supposed to, misappropriation of funds. What are the sanctions for each of the above? Who enforces the sanctions?

2. How are conflicts resolved? Give the process for the above mentioned conflicts.

- ❖ Is the existing SS irrigation organization (WUA) of the project efficient?

Annex C: Pictures

Figure 1: Photo captured during canal discharge measurement

Figure 2: Degraded upper watershed area around the schemes

Figure 3: Cabbage farm at Bossa scheme

Figure 4: Downstream scouring problem at Bossa scheme

Figure 5: Canal siltation, and grass and weed growth problem at Ella

Figure6: Sedimentation problem at Ella scheme

Figure 7: Traditional water diversion system illegally