



**Environmental and Socio-economic Impacts of Small Scale
Irrigation Farming Households in Central Rift Valley of Ethiopia**

Engdasew Feleke Lemma



**A Dissertation Submitted to the Center of Environment and Development
Studies, College of Development Studies**

**Presented in the Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Development Studies (Environment and
Development)**

Addis Ababa University

Addis Ababa, Ethiopia

November, 2020

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Addis Ababa, Ethiopia

November, 2020

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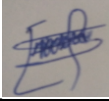
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Environmental and Socio-economic Impacts of Small Scale Irrigation Farming Households in Central Rift Valley of Ethiopia

Abstract

Smallholder rain-fed agriculture is the mainstay of the majority of the population in Ethiopia. However, the performance of the sector is very poor particularly in the drought-prone parts of the country. Small scale irrigation has been introduced to overcome climate variability induced livelihood challenges of farm households; Central rift valley of Ethiopia is known for its long time experience in irrigation. This research aims to examine the environmental and socio-economic impacts of small scale irrigation in the Central Rift Valley of Ethiopia. Household survey, interview and soil and water laboratory testing were used to collect primary data. About 259 irrigation users and 172 non-irrigation user households were selected for the survey. Convenience and snowball sampling methods were used to select interviewees. The study showed that irrigation user households have higher gross income and farm income than non-irrigation users ($P < 0.01$ and $P < 0.05$ respectively). Irrigators have higher cultivated land holding (0.89 hectares) than non-irrigators (0.84) at $P < 0.05$. The highest percentage of irrigators (71%) and non-irrigators (77%) have never used credit service. Many complex factors determine farmers' decision to participate in irrigation. Poor market access due to road problems and lack of transparency in the performance of the local irrigation institutions found to be among the critical constraints that negatively affect farmers' decision to participate in irrigation. The current study revealed that irrigation water that falls with the value of SAR > 15 and Adjusted ESP > 13 at EC < 4 ds/m indicates the sodic nature of the water. Accordingly, the groundwater chemical composition (ESP = 63.3, SAR = 116.28 and EC = 1.973), showing the sodic type of the water at Bochessa site. Thus, the study proofed that the type of the irrigation water affects the quality of the soil (farm lands irrigated using groundwater have high ESP (ESP=29.7)) and the soil is categorized as sodic soil. Sodic soils adversely affect plant growth mainly hindering the osmotic process and diminishes the economic profitability. The study further revealed that small scale irrigation enhances agricultural productivity, serve as a source of diversified food, creates employment opportunity, means to cope up with the effects of climate variability, and increases household asset and income. However, the prevalence of pests and diseases, degradation of natural resources, and biodiversity modification are some of the negative effects of irrigation. Water scarcity and associated conflicts for water use found to be a serious problem due to the high demand for water from multiple users. The sustainability of irrigation-based livelihood is gloomy in the study site due to farmers' limited access to livelihood capitals, unequal participation of women farmers in irrigation, and lack of transparency of irrigation institutions. The study suggested that creating market linkage, increasing accessibility of rural financial institutions, introducing gender-sensitive irrigation technologies, adopting of water-saving irrigation technologies and ensure equity in irrigation water use as key approaches to enhance the sustainability of irrigation. The study further recommends assuring sustainable rural livelihood agricultural policymakers and practitioners should focus on improving the performance of both rain-fed and irrigation. The study suggests some future researches to be conducted on the effects of SSI farming on human health and biodiversity change and how the environmental impact assessment is implemented by large scale irrigators in the CRV of Ethiopia.

Keywords: *Small scale irrigation, farmer participation, household income, determinants, soil salinity, livelihood, Central Rift Valley.*

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Acronyms and abbreviations

ADLI	Agricultural Development Lead Industrialization
AWM	Agricultural Water Management
CRV	Central Rift Valley
DA	Development Agent
ETB	Ethiopian Birr
DFID	Department for International Development
EPRDF	Ethiopian People's Revolutionary Democratic Front
FAO	Food and Agricultural Organization
FHHH	Female Headed Households
HH	Household
HHH	Household Head
GDP	Gross Domestic Product
IFAD	International Fund for Agricultural Development
IIED	International Institute for Environment and Development
IRLI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
KII	Key Informant Interview
MGD	Millennium Development Goal
MHHH	Male Headed Household
MLE	Maximum Likelihood Estimation
MoA	Ministry of Agriculture
MoFED	Ministry of Finance and Economic Development
MoWR	Ministry of Water Resources
NGOs	Non-governmental organization
OLS	Ordinary Least Square
PVC	Polyvinyl Chloride
SSA	Sub-Saharan Africa
SSI	Small Scale Irrigation
SSIS	Small Scale Irrigation Scheme

TLU Total Livestock Unit
UN United Nations
UNEP United Nations Environmental Programme

List of publication

1. Engdasew Feleke, Engdawork Assefa, Tesfaye Zeleke .(2019). Blessings and blights of small scale irrigation on the livelihood of smallholder farmers in the Central Rift Valley of Ethiopia. *Journal of Sustainable Development in Africa*, 21(3), 34-63. ISSN: 1520-5509.
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3. Soil salinity problems, effects and ameliorative measures in small scale irrigation in Ethiopia: empirical evidence from the central rift valley of Ethiopia (**accepted, Ethiopian Journal of Biological Sciences**).
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Chapter 1: Introduction

1.1 Background of the study

Smallholder farmers in developing countries are predominantly affected by the impacts of global climate change as they are highly vulnerable due to their mostly tropical locations and to the socioeconomic, demographic, and policy-related trends limiting their capacity to adapt to change (Mertz, Halsnæs, Olesen & Rasmussen, 2009). The livelihood of African farmers is more vulnerable to climate change, variability, and hazards due to their heavy dependence on rain-fed agriculture (Intergovernmental Panel on Climate Change (IPCC), 2007). Smit and Pilifosova (2003) further noted that most countries in Africa are particularly vulnerable to climate change because of limited adaptive capacity due to the prevalence of widespread poverty, unequal land allocation, drought occurrence, and the economy depends on rain-fed farming system.

In Sub-Saharan Africa (SSA), agricultural development is the main vehicle to end poverty. However, insufficient and variable rainfall, and drought are common problems of agricultural development (You, 2008). Consequently, climate change, in particular, has threatened smallholder rain-fed agricultural production and has increased the vulnerability of people dependent on it for their livelihood as it caused welfare losses (IPCC, 2014; Komba & Muchapondwa, 2012; Lipper *et al.*, 2014). Claessens *et al.* (2012) indicated that SSA is expected to experience significant negative impacts of climate change. The area suitable for agriculture, the length of growing seasons, and yield potential are expected to decrease particularly in the margins of arid and semi-arid parts of Africa. This situation would compromise food security and exacerbate malnutrition in the continent content. In some countries, agricultural yields of rain-fed farming could be reduced by up to 50 percent by 2020 (IPCC, 2007).

In terms of projection on population growth, the SSA region will account for about half of the global population growth between 2010 and 2050 (United Nations (UN), 2011). SSA might also face a serious challenge to feed more than 2 billion people by 2050 due to the adverse effect of climate change on rain-fed agriculture (IPCC, 2007). The projected high population growth suggests an increase in future food demand and consequently an increase in demand for irrigation water (Mancosu, Snyder, Kyriakakis, & Spano, 2015). With the rapid rate of global population growth, the contribution of irrigation towards

boosting agricultural production is enormous. If an irrigated area could be tripled by 2050, it would dramatically contribute to the food supply in SSA because irrigation is almost twice more productive than rain-fed farming (Rosegrant, Ringler, & Zhu, 2009). In some emerging and least developed countries, irrigation development is a backbone for the nations' welfare and for feeding their vast population (Food and Agricultural Organization (FAO), 2006). On coverage, only 20% of the world's total croplands are irrigated, which are contributing to 40% of the global agricultural harvest (IFAD, 2014; Hess, 2010). Based on the projection made by Steduto, Hoogeveen, Winpenny, & Burke (2017), to meet the increasing demand for food by 2050, the global agricultural production would need to increase by 60% of the production in 2005.

The entire situation has implications on the necessity of expanding irrigation to produce more food for the growing world population. However, water scarcity will be the critical challenge of future irrigation expansion as a result of climate change-induced drought and high competition for water between agriculture and other sectors, unless appropriate water supply enhancement and demand management activities are implemented (Mancosu *et al.*, 2015; Steduto *et al.*, 2017). Smallholder farmers and the rural poor are often suffering due to lack of access to water for production purposes, and entrenching into poverty (Forouzani and Karami, 2011). Agricultural water scarcity has the potential to become a key limiting factor for livelihood generation among the rural poor in Africa, South-East Asia, and Central and South America with growing water demand from all water users (Namara *et al.*, 2010). Assefa, Biazin, Muluneh, Yimer, & Hailelassie (2016) highlighted agricultural water scarcity as critical challenge of agricultural production particularly in the dry lands of SSA. This has implications on the need to emphasize strategies that can improve investments in agricultural water management to support smallholders' livelihood with particular attention in SSA.

Thus, focusing on sustainable agriculture is not a luxury in the situation where the agricultural resource bases erode beyond a certain point and the civilization it has supported collapses (Fischer, Shah, & Velthuizen, 2002). Lipper *et al.* (2014) indicated that the threat of climate change on livelihood can be reduced by increasing the adaptive capacity of farmers, increasing resilience, and resource use efficiency in agricultural production systems. However, vulnerable groups of the population have only limited capacity to resist extreme events such as droughts and floods, compounded with their suffering from the effects of large-scale environmental problems related to changing climate, loss of biodiversity, and

deterioration of land. Thus, Fischer *et al.* (2002) underlined the need for policy responses to enhance adaptive capacity in the short and long term contexts to ensure sustainable agricultural development. Policymakers are expected to cope with the high risks of shocks that affect their economy, which consequently results in degrading the welfare of the poor group of their population. Government policies that reduce pressure on resources, improve management of environmental risks, and increase the welfare of the poorest members of society can simultaneously advance sustainable development and equity, and enhance adaptive capacity and coping mechanisms (Fischer *et al.*, 2002).

In Ethiopia, smallholder rain-fed dependent farmers have been facing climate-related hazards due to rainfall variability and droughts (Hagos, Makombe, Namara, & Awulachew, 2009; Kassie *et al.*, 2013). The rainfall pattern in most regions of Ethiopia is not conducive to crop production because of its erratic nature. It rains only for a few months of the growing season and is usually short and intense, causing high runoff (Yihun, 2015). Prolonged and recurrent drought adversely affects the livelihood of the agricultural communities and the economy as a whole (Awulachew, 2019). High temperatures result in the reduction of agricultural productivity, while also creating a conducive environment for weed and pest proliferation (Yihun, 2015). Changes in precipitation result in crop failure in the short-run and production decline in the long-run (Araya and Stroosnijder, 2011). Awulachew *et al.* (2005) pointed out that in Ethiopia, the drylands occupy 70 percent of the landmass and 45 percent of the arable land, but the area has a fragile natural resource base and crops suffer from moisture stress and drought even during normal rainfall seasons. Farm productivity has declined substantially and farmers find themselves sliding into poverty.

To overcome these climate change-induced vulnerabilities of crop failure, famine, poverty, food insecurity, and livelihood hazards, irrigation can serve as the solution for rural economies in the developing part of the world (Turrall *et al.*, 2010). Irrigation plays a big role in increasing rain-fed dependent farmers' resilience capacity against changing climate (Awulachew *et al.*, 2010). If agriculture is fully dependent on the rain-fed system, no rain means no agriculture. This has implications for the benefit of irrigation to agricultural production. Irrigation is the prime means of intensification and will remain a keystone in food security policies in the face of climate variability (Awulachew *et al.*, 2010). Small scale irrigation (SSI) is very promising in developing countries; it can enhance rural food security, poverty alleviation, and adaptation to climate change. It enables households to increase their resilience and, in some instances, transform their livelihoods (Tucker and Leulseged, 2010).

Concerning the government's policy, the Ethiopian government has given policy priority to irrigation and water-based development in many of its agricultural development programs. Ethiopia has introduced a national irrigation development strategy to use water and land potential to increase agricultural production (Ministry of Water Resources (MoWR), 2001). Irrigation development has already been identified as a vital tool to promote sustainable economic growth and rural development and to ensure food security and poverty reduction (MoWR, 2002; Ministry of Finance and Economic Development (MoFED), 2006). Based on this supportive policies, concerted efforts have been made to expand irrigation development in the country particularly from 2005 to 2006 to address the problems of rain-fed agriculture and to enable sustainable growth and development (Hagos *et al.*, 2009).

The Ethiopian government has undertaken various activities to expand irrigation in the country. The country's Agricultural Development Led Industrialization (ADLI) strategy considers irrigation development as a key strategy for sustainable agricultural development. Thus, irrigation development, particularly SSI is planned to be accelerated (MOFED, 2010). About water resources, Ethiopia has 12 river basins, abundant rainfall, and groundwater reserves and based on this the country is known by saying "Ethiopia is the water tower of East Africa". The irrigation potential of the country is estimated to be about 3.7 million hectares, but only 20 to 23 percent of this potential is utilized under irrigated agriculture (Ministry of Agriculture (MoA), 2011a). Previous studies conducted in the field confirm that if Ethiopia's water resources are developed cater for irrigation, it would be possible to attain enough agricultural surplus both for domestic consumption and for external markets (Yihun, 2015).

1.2 Problem statement

In the study area, Central Rift Valley (CRV) of Ethiopia rapid population growth, poverty, and natural resource degradation are firmly intertwined (Ayenew, 2007; Jansen *et al.*, 2007; Pascual-Ferrer, Pérez-Foguet, Codony, Raventós, & Candela, 2014). The main livelihood strategy for the majority of the population (about 2 million) in the CRV is the small mixed rain-fed farming system comprising cereals such as wheat, barley, maize, and Teff (the dominant staple food item used to prepare Ethiopian Injera) and livestock (Getnet, Hengsdijk, & van Ittersum, 2014). However, extreme rainfall variability has a serious impact on food security in the area due to the dependency of the population on climate-sensitive

subsistence rain-fed farming systems like most smallholder farmers in Ethiopia (Muluneh, Bewket, Keesstra, & Stroosnijder, 2017; Yihun, 2015). Rain-fed farming is very susceptible to water shortage in CRV due to large variability in rainfall distribution between years and within years coupled with short rainy seasons (Yihun, 2015). According to Belay *et al.* (2017), erratic rainfall forced farmers to discontinue crop planting and some farms left uncultivated due to the late onset of the main rainy season, which usually starts late and recorded low rainfall amounts. Based on the study by Bekele *et al.* (2010) in the CRV area, the rain-fed farming system gives very low crop yields varying between 230 to 400 kg/ha for maize and 69 to 150 kg/ha for Teff. Having such small yield, the majority of the farm households have not yet attained food security and under food relief support from year to year, which sometimes reaches 50 percent of the population.

In addition to erratic rainfall situation, the occurrence of recurrent drought is the other stressor that constrained the performance of rain-fed agriculture in the CRV of Ethiopia. According to the study by Gizachew & Shimelis (2014), climate risk quantified in terms of drought frequency revealed that all the districts in CRV experienced drought ranging from 2 to 5 times within 33 years. Adami Tulu-Jido-Kombolcha (ATJK) and Ziway Dugda (study districts) were among the worst-hit districts, which experienced the highest frequency of drought (5 times in 33 years). Gizachew (2012) also revealed that ATJK and Ziway Dugda districts had the highest probability of severe drought occurrence with 46 to 76% severity level in the East Shoa zone of Ethiopia. The study by Melka, Kassa, Ketema, Abebaw, & Schmiedel (2015) in the CRV region of Ethiopia households reported that about 63% of the shocks were droughts in the previous five years period and this drought shock is highly pronounced in low land agro-ecology. Thus, under such drought shocks, both livestock and crop production activities were severely affected making it difficult for farmers to maintain food security. Consequently, the CRV area is found to be one of the chronically food-insecure parts of Ethiopia where the Productive Safety Net Programme (PSNP) has actively been implemented. In general, the performance of rain-fed agriculture is very poor as a result of the erratic nature of rainfall and recurrent occurrence of drought, which are still prevailing problems in the area (there was even a chronic drought in the study districts during the data collection period of this study).

The preceding paragraphs indicated that dependency on the rain-fed farming system is a less promising economic activity to support the livelihood of farming households, who are living under the threat of

climate variability and drought in areas like the CRV of Ethiopia. Therefore, SSIs have been expanding in CRV based on government policy advocacy on irrigation development in Ethiopia to overcome the adverse effects of chronic drought and rainfall variability on the livelihood of smallholder farmers. Irrigation development and expansions are carried out by the concerted efforts of the government and non-governmental organizations. As a result, CRV is among the areas in Ethiopia characterized by a long history in the expansion of SSI. SSIS has been developed on lakes, stream and river diversions, groundwater, dams, and perennial springs in the CRV.

Concerning the water resource endowments in the CRV area, the area is characterized by the existence of four interconnected lakes such as Langano, Abyata, Shala, and Ziway; there are also streams and ecologically valuable wetlands (Jansen *et al.*, 2007). In addition to the SSI farming, large scale national, and foreign horticulture and floriculture farms have been operating in the area taking the available water resources as an advantage (Hengsdijk & Jansen, 2006). Thus, the area is characterized by the existence of high competition for water resources among large and small scale irrigators, commercial fishery, industrial and domestic water use, nature, and related eco-tourism. Consequently, there are competing claims for land and water resources in the CRV among multiple users (Jansen *et al.*, 2007; Pascual-Ferrer *et al.*, 2014). Being a closed basin, relatively small intervention in land and water resources can have far-reaching consequences for ecosystems, goods, and services, and potentially undermine the sustainability use of the area.

This research was initiated with the perspective that SSI is an important agricultural technology to averse the negative effects of climate variability on farm household livelihood in the drought-prone CRV of Ethiopia. Considering the existing situation on the ground and based on literature, the CRV area is characterized by the prevalence of poverty and food insecurity though there is an expansion of SSI to improve farm HHs livelihood (Jansen *et al.*, 2007; Pascual-Ferrer *et al.*, 2014). Therefore, it is imperative to have a thorough understanding of the problems why climate variability induced livelihood vulnerabilities, which are manifested in the form of deep-rooted poverty, chronic food insecurity and households' reliance on food aid in CRV still a persistent challenge though SSI farming has been introduced to halt such unwanted livelihood outcomes. Furthermore, the CRV of Ethiopia has long time experience in SSI farming. Thus, understanding the environmental and socio-economic impacts of SSI on

farm households is quite crucial for the future successful SSI development and expansion endeavors in the country and other countries having similar socio-economic and environmental contexts.

The first theme of this research aims to identify the determinants that affect farmers' decision to participate in irrigation farming, examine the effects of irrigation on household income and explore the types of farmers' participation in the management of irrigation schemes. In the previous research works by authors from different parts of the world different factors affect farmers' decision to participate in irrigation, for example (Asayehegn *et al.*, 2012; Belay & Beyene, 2013). They came up with different results. However, there is no similar study in the CRV of Ethiopia. Thus, at this venture, it is critically important to identify the determinants that affect farmers' participation in irrigation farming and management of schemes. This part of the investigation is crucially important to analyze the environmental and socio-economic impacts of SSI because community participation has its implication on the sustainability of irrigation schemes.

In the investigation of the environmental impacts of SSI much focus is given on the analysis of the impacts of SSI on the soil. Irrigation farming has been threatened due to problem salinity particularly in coastal areas (Hanson, Grattan, & Fulton, 2006). The same phenomenon is happening in CRV where groundwater based irrigation practices are common. In Ethiopia, the total land area covered by salt-affected soil is estimated to be 11,033,000 hectares. Such areas are mainly found in the rift valley zone, where groundwater has been used as a source of irrigation water (Seid & Genanew, 2013). Concerning previous research on the impacts of SSI on the environment, the condition of soil salinity and SSI were investigated by some scholars (Assefa & Kibret, 2016; Seid & Genanew, 2013; Zewdu, Suryabhadgavan, & Balakrishnan (2017). Other scholars have undertaken studies on soil salinity status on large scale irrigation schemes (Asmamaw, Haile, & Abera, 2018; Kitila, Gebrekidan, & Alamrew, 2014). Ulsido, Demisse, Gebul, and Bekelle (2013) investigated the environmental impacts of SSIS in the Rift Valley Lakes Basins. Although CRV is a hot spot area due to the pressure exerted on the water and land resources as a result of the expansion of both SSIS and large scale floriculture and horticulture farms, there are scanty of research works on the environmental impacts of irrigation.

Thus, knowledge about the soil salinity status, irrigation water quality, and other environmental impacts of SSI have a vital role to identify the type of salinity, sources of salinity, and other environmental-related problems of SSI using groundwater and river as a source of irrigation water. Therefore, the finding of this

research has a significant contribution to providing information for land reclaiming options and decisions on soil amendment in irrigated fields to sustain the farmers' benefit out of SSI in the study site, where rain-fed agriculture is highly vulnerable to extreme rainfall variability resulting crop failures and food insecurity. The sustainability of irrigation agriculture largely depends on the sustainable use of biophysical resources, hence, this study can be a good mirror to reflect the status of SSI farming in CRV in the view of sustainable development. Therefore, the outcomes from this research could be applied to other similar areas within SSA, where ensuring sustainable agriculture is a policy priority in the face of a changing climate.

Concerning socio-economic impacts of SSI, previous research on SSI in Ethiopia mainly attempted to analyze the positive impacts of SSI on HH income (Astatike, 2016; Ayele, Nicholson, Collick, Tilahun, & Steenhuis, 2013; Gebremariam & Ghosal, 2016; Hirko, Ketema & Beyene, 2018; Yihdego, Gebru & Gelaye, 2015), the impact of SSI on food security (Abdissa, Tesema & Yirga, 2017; Gebrehiwot, Mesfin, & Nyssen, 2015; Tefera & Cho, 2017; Tesfaye, Bogale, Namara, & Bacha, 2008) and impact of SSI on HH poverty (Ayele *et al.*, 2013; Bacha, Namara, Bogale, & Tesfaye *et al.*, 2011; Hagos, Jayasinghe, Awulachew, Loulseged & Yilma, 2012; Haji, Aman, & Hailu, 2013). Mengistie and Kidane (2016) investigated the impact of SSI on HH livelihood improvement. The results of these researchers reported the positive contribution of SSI on-farm HH income, food security, poverty, and livelihood. On the other hand, Asayehegn (2012) investigated the negative impact of SSIS in Tigray, Ethiopia. The review of the previous research works on impacts of SSI in Ethiopia revealed that the focus of the researchers on investigating the positive impacts of irrigation, however, the undesired outcomes of SSI farming were not well addressed in the previous research works to the best of our knowledge. Therefore, this research was undertaken to fill this knowledge gap on the undesired outcomes of SSI. Designing a sustainable development pathway is critical while managing the different resource claims in the CRV. Thus, the result of this research can serve as valuable input for policymakers and development practitioners about SSI development towards enhancing sustainable rural livelihood strategies in the era of climate variability examining both the positive and negative impacts of SSI and identifying the factors that affect the impacts of SSI on the household economy.

Furthermore, in this research investigation is done on the participation of farmers in SSI, features, challenges and livelihood sustainability in the context of gender. Gender consideration in the analysis of this research is believed to be important to verify the existing debits on the literature on gender and agricultural technology adoption like SSI. Fischer *et al.* (2002) indicated that in combatting the adverse effect of climate change the most pressing challenge is to strengthen the social, economic, and environmental resilience of the poorest and the most vulnerable group of the community particularly women farmers. Climate variability and hazards have potential adverse effects to further widen the gap of inequalities and exacerbate the undesirable outcomes of the marginalization of women in rural development (Knapman & Sutz, 2015). Van Koppen, Hope, and Colenbrander (2013) noted that if there is the adoption of SSI at significant scales by both men and women, irrigation can become a basic trigger for agricultural growth in SSA; such mode of agricultural growth can become extraordinary. The results of the previous investigations have similarities reporting the existence of gender bias in which women found to have a limited role as irrigation users and decision-makers in the majority of investigated SSIS in Ethiopia (Awulachew, 2019; Haileselassie *et al.*, 2016; Yohannes & Gebrerufael, 2016). Other researchers such as Nigussie, Lefore, Schmitter, and Nicol (2017) and Theis, Bekele, Lefore, Meinzen-Dick, and Ringler (2018) reported the difference in the technological preference of women and men. Equity, in this context considering gender, among the social groups is the key concept towards ensuring sustainable rural development. The topic of gender and SSI in Ethiopia is among the less addressed topics and this motivated the researcher to investigate the challenges and opportunities of SSI in the perspective of gender.

Methodologically, most of the previous research works on the impacts of SSI were focused on the assessment of the positive effect of SSI on HH income, food security, and poverty situation employing quantitative research techniques with less attention to qualitative data. However, in the current study, the research aims to examine the negative and positive effects of SSI on environmental resources and socio-economic aspects and the challenges of SSI development and scrutinize the implication of the finding for sustainable livelihood development. There are hardly other studies on the environmental and socio-economic impacts of SSI connecting the impacts with the sustainable livelihood of the farming households. Furthermore, the CRV area has a significant ecosystem, economic and social values for

different sectors, thus, it creates motivation for the researcher to investigate such globally and nationally valuable sites. Thus, this research was undertaken to address research questions such as why the level of farmers' participation in SSI varies, how the environmental and socio-economic aspects are affected by SSI farming practice and what are the challenges of SSI enhancement? Do the environmental and socio-economic impacts of SSI have implications for sustainable livelihood development in the CRV area?

1.3 Objective of the study

The general objective of the study is to investigate the environmental and socio-economic impacts of small scale irrigation farming households in the CRV of Ethiopia. Specifically, the study was intended to:

1. Examine the effects of SSI farming on soil salinity;
2. Assess the state of farmers' participation decision to work in SSI farming and the its effect on HH income;
3. Identify and analyze the positive and negative effects of SSI on rural livelihood and environmental resources.

1.4 Scope of the study

The study was conducted in the CRV of Ethiopia. This research was undertaken in the Central Rift Valley of Ethiopia. It was delimited to the low land districts of Adami Tulu Jido Kombolcha (ATJK) and Ziway Dugda as these districts are highly prone to the recurrent occurrence of drought and rainfall variability induced crop failures, which makes SSI farming very essential in the area. Although the research is delimited in these two low land districts of the CRV, the result of the study can be useful and applicable to similar districts in the region specified and even beyond. The study focuses on the environmental and socio-economic impacts of SSI agriculture investigating both positive and negative impacts of SSI using a holistic and livelihood centered approach. Synthesis of the findings was done to analyze the implication of the finding for sustainable rural livelihoods.

1.5 Conceptual framework of the study

Smallholder farmers' investment decisions in irrigation farming can be influenced by several interrelated factors when they operate under imperfect information and market conditions. Understanding the investment decisions of the resource users and the factors that drive such decisions will allow designing effective strategies for upscaling the contribution of technologies (like irrigation). This would provide insights on how policymakers and development practitioners motivate and tailor farmer resource use, production, and investment strategies towards win-win pathways that improve livelihood situations and enhance future production possibilities (Shiferaw & Bantilan, 2004). The conceptual framework for this study is developed based on farmer-first and sustainable livelihoods principle (Chambers, 1987; DFID, 2000). It also includes the theory of farm-household behavior (de Janvry *et al.*, 1991), theories on the economics of rural organizations (Hoff *et al.*, 1993), the influence of institutions, and economic policies by Heath and Binswanger (1996).

Smallholder farmers' investment and production decisions are based on expectations to maximize their livelihood benefits over a period of time considering existing resource bases and expected shocks. Thus, the current global and local situations related to climate variability, poverty, and food security are the drivers that push smallholder farmers to decide working in irrigation farming as can be seen from the conceptual framework (Figure 1.1). These decisions are also affected by existing institutional and organizational structures that are working on infrastructural investments, access to new technologies, and integration of the input-output market at the local level (Shiferaw & Bantilan, 2004). Thus, there is a need to holistically integrate different factors that enhance agricultural productivity because providing irrigation water alone will not guarantee increased productivity. The level of farmers' participation in irrigation scheme management has a tremendous impact on determining the success of the irrigation development intervention (Delaney, 2012). Collective action plays a key role in farmers' participation in irrigation scheme management. According to Sharaunga & Mudhara (2018), the problem of institutional failure and lack of compliance to rules governing schemes results in poor participation, which consequently leads to scheme de-generation into open access resources as defined by 'tragedy of the commons'. Hardin (1968) in the theory of 'tragedy of the commons' stated that participation in collective action is influenced by the natural selfishness of humans and the rational self-interest against the common good.

In this regard when more profitable resource-conserving or improving technologies are available, and capital, knowledge, information, policy, and institutional constraints are not limiting, farming households can undertake productivity-enhancing resource investments (such as irrigation). In the conceptual framework (Figure 1.1) working in SSI is considered as an agricultural intensification using improved seed varieties and other productivity-enhancing inputs as strategies towards achieving livelihood objectives by enhancing adaptation strategy to rainfall variability and chronic drought. The smallholders' participation in productivity enhancing agricultural technologies (SSI in this context) will in turn determine the livelihood and environmental resources outcomes in the next period. In a dynamic sense, improved level of well-being and better stock of environmental resource conditions will in turn enhance the stock of livelihood assets available for production, consumption and investment decisions in the subsequent periods as the double arrow show between the outcomes from irrigation and households' livelihood assets in Figure 1.1.

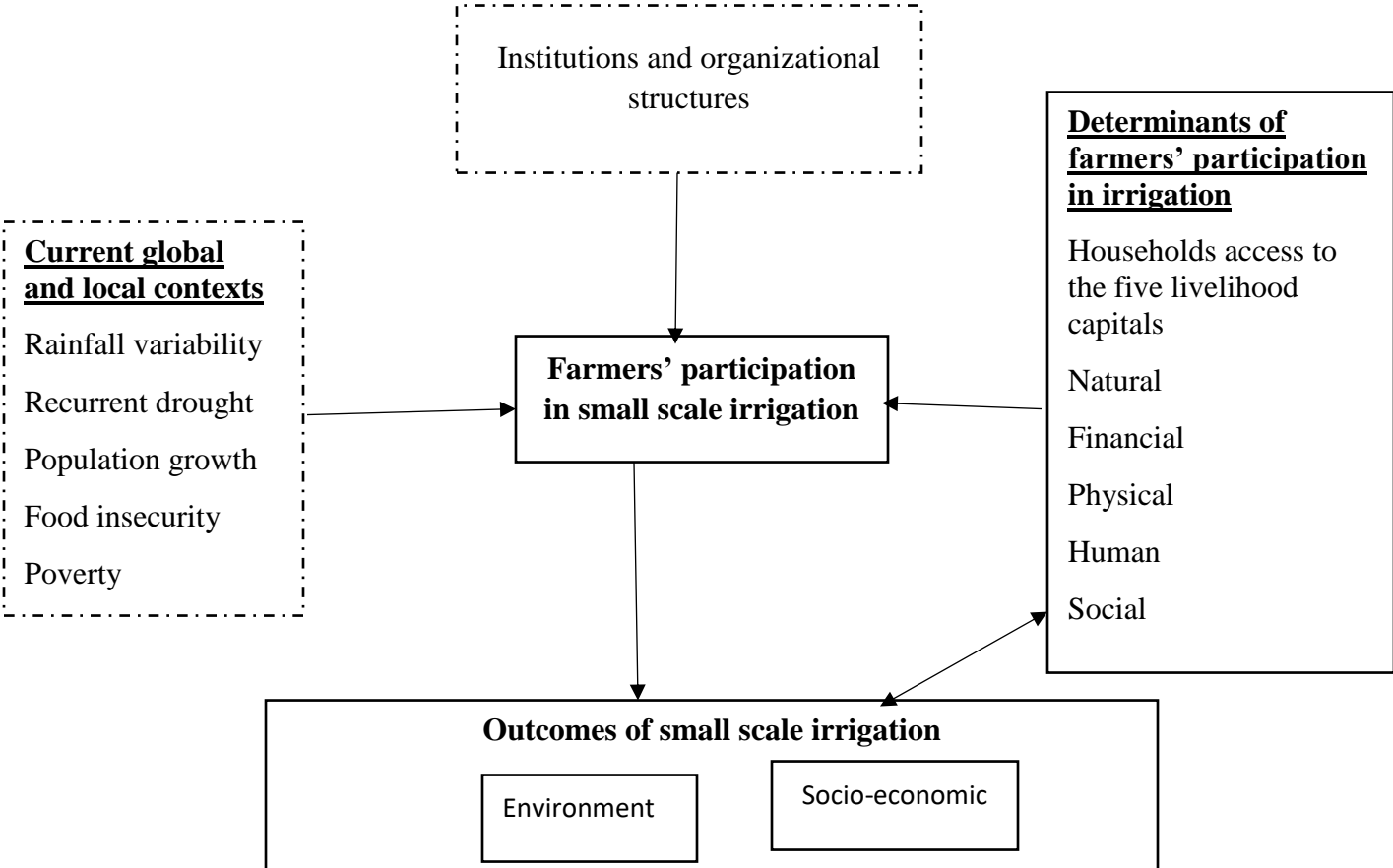


Figure 1.1: Conceptual framework. Source: Researcher's own construction based on (Chambers, 1987; DFID, 2000).

In the absence of enabling policies and institutional situations that encourage investment in irrigation and other productivity enhancing agricultural technologies, smallholder farmers lack the economic rationale to participate in irrigation farming. Hence, the interface of lack of viable option to invest in irrigation and adverse biophysical, socio-economic, policy and institutional environments may force smallholder farmers in marginal areas to practice more exploitive and unsustainable/less sustainable livelihood strategies (Shiferaw and Bantilan, 2004).

The livelihood of the rain-fed dependent farmers is extremely vulnerable due to climate change induced hazards like rainfall variability and occurrence of recurrent drought especially in arid and semi-arid areas (IPCC, 2007). CRV of Ethiopia has been facing such types of livelihood vulnerabilities due to climate change and recurrent drought. Such situations together with rapid population growth have increased the level of vulnerability of smallholder farmers to be able to cope with livelihood strategies towards achieving enhanced living condition, for example, prevalence of food insecurity and poverty are the major challenges. In Ethiopia, irrigation development has already been identified as an important tool to stimulate economic growth and rural development (MoWR, 2002). The current study examine the determinants of farming households' decision to participate in SSI. Furthermore, the study analyze the environmental and socio-economic impacts of SSI farming. The outcomes of irrigation can be positive, negative or both positive and negative due to many factors (Amede, 2015). The nature and type of the outcomes of irrigation has implication on the sustainable development of rural livelihoods. The sustainability issue of livelihoods are categorized into two groups such as environmental and socio-economic sustainability (Chambers & Conway, 1992). Environmental sustainability refers to the internal capacity of livelihoods to withstand outside pressures. According to most of the conventional thinking sustainability refers to preservation or enhancement of the productive resource base, particularly for future generations. Socio-economic sustainability refers to whether a human unit (individual, household or family) cannot only gain but maintain an adequate and decent livelihood in terms of equity.

A livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term (Chambers & Conway, 1992).

This study makes an in depth investigation on the outcomes of irrigation farming from environmental, economic and societal aspects and examine its implication for the sustainability of rural livelihoods in the CRV of Ethiopia where rain-fed agriculture is under the threat of rainfall variability and drought. Thus, in the study consideration is done on the identification of the positive and negative impacts of irrigation, challenges irrigators faced, equality in using agricultural resources, gender contexts in participating at irrigation farming and sharing benefits from irrigation. Finally, discussions, conclusions and policy implications are given taking sustainable livelihood framework into consideration. In this conceptual framework the boxes indicated in dashed lines are not analyzed in the current research and can be potential future research areas.

1.6 Description of the study area

Central Rift Valley (CRV) of Ethiopia is located between, approximately 38°15'E to 39°25'E and 7°10'N to 8°30'N. It is situated in the administrative regions of Oromia and the Southern Nations Nationalities and Peoples Region (SNNPR), and covers an area of approximately 10,000 km².

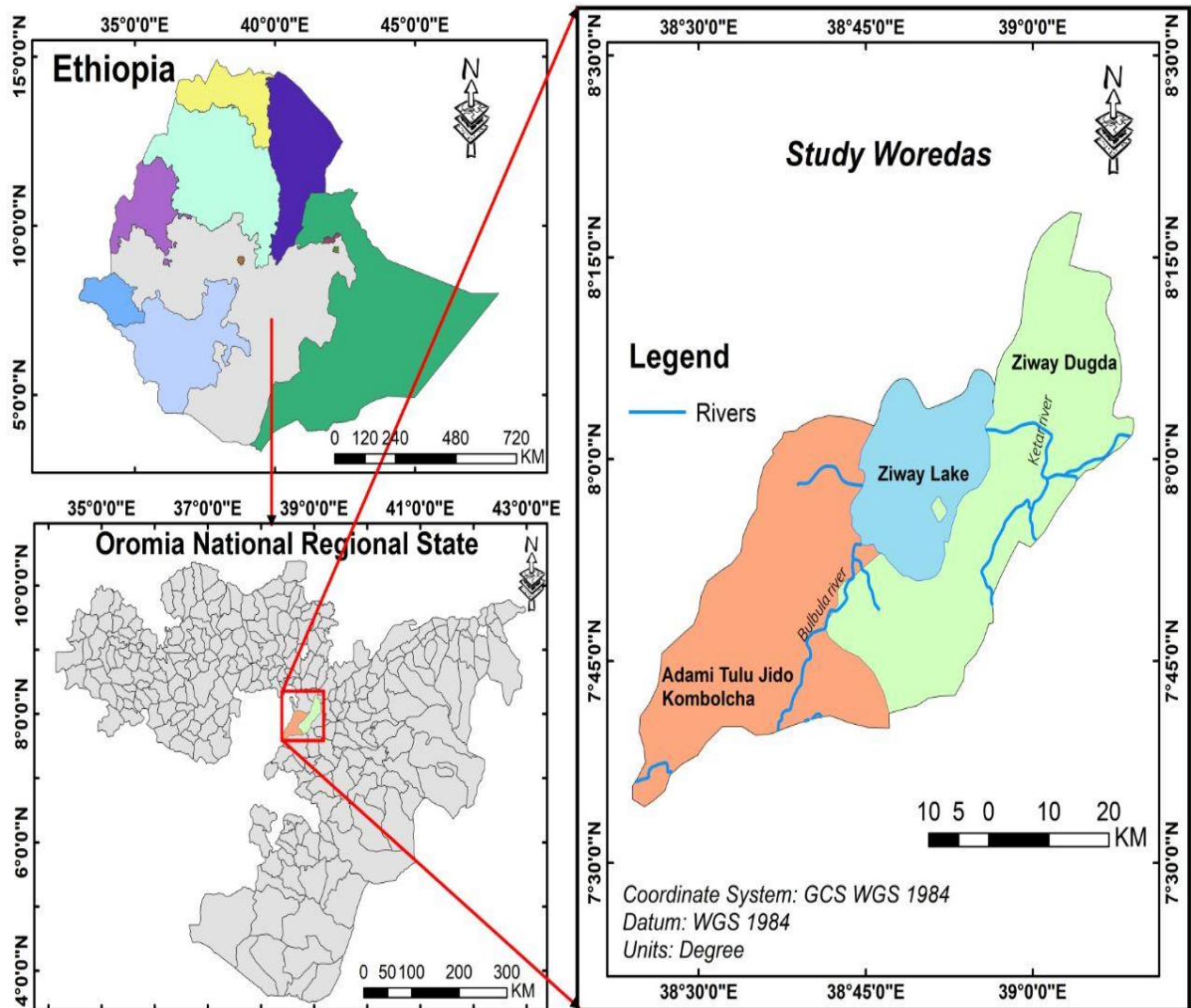


Figure 1.2: Study Area

The climate of CRV of Ethiopia varies depending on altitude. The main rainy season ranges from June to September in which about 70% of rainfall precipitates. There is short rainy season from March to May (Getnet *et al.*, 2014). The mean annual precipitation is 900mm, however, there is local variability of precipitation depending on altitudinal variation (Muzein, 2006; Pascual-Ferrer

et al., 2014). The rainfall amount varies from 600mm in the central lowlands to about 1600mm yr⁻¹ in the highlands (Getnet *et al.*, 2014). The temperature of the area also varies based on altitude, the annual average daily temperature of about 16 °C in the eastern and western highlands (3000 m a.s.l) increases to 21 °C in the central lowlands (1600 m a.s.l) (Getnet *et al.*, 2014). The area is characterized by relatively high temperature. February to April are the hottest months while the lowest average minimum temperature recorded in the months of October to December. Most of the lowlands in the CRV is characterized with arid or semi-arid climate situation, erratic rainfall, and frequent drought occurrence (Meshesha, Tsunekawa, & Tsubo, 2012). The monthly average precipitation of the area is prepared for 15 years (2003 – 2017) and presented as shown in Figure 1.3. The main rainy season ranges from June to September and the dry season is from October to March with variable and low average monthly precipitation. There is local variability of precipitation depending on altitudinal variation (Muzein, 2006).

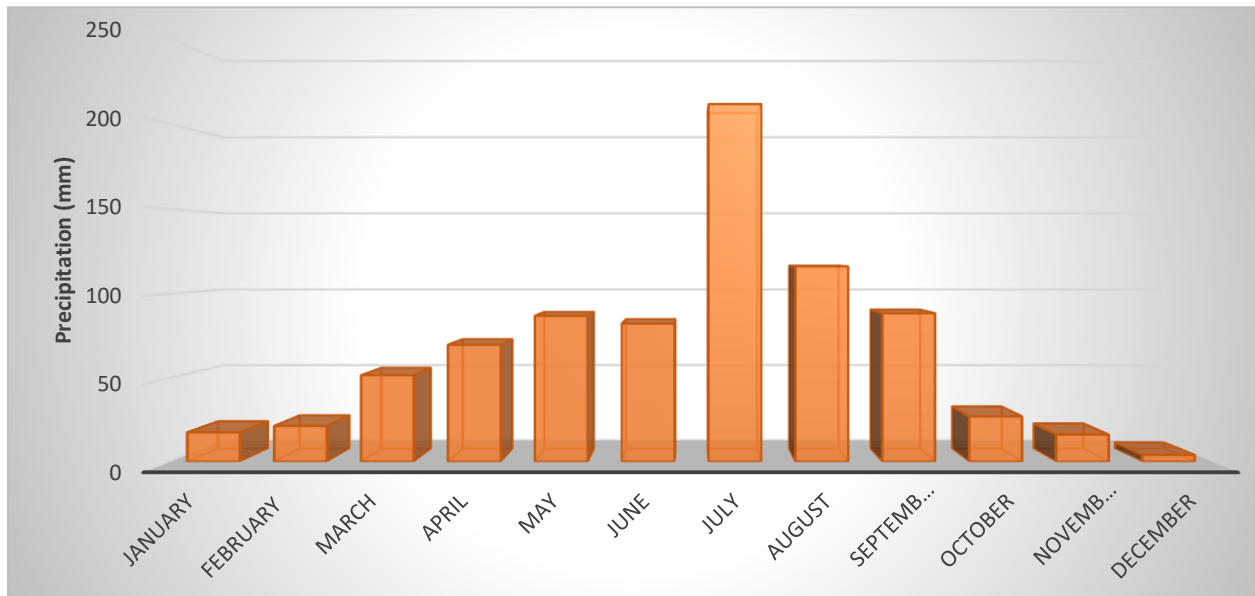


Figure 1.3: Monthly average of 15 years precipitation of Ziway station (Source: Ethiopian National Meteorology Agency, 2003-2017).

The area is characterized by relatively high temperature. The 15 years (2003-2017) monthly average maximum and minimum temperature of the area is presented in Figure 1.4. February to April is the hottest months having the highest average maximum temperature nearly 30°C. The lowest average minimum temperature recorded in the months of October to December. According

to Gizachew & Shimelis (2014), all the districts in the CRV experienced severe drought risks at different times in the past.

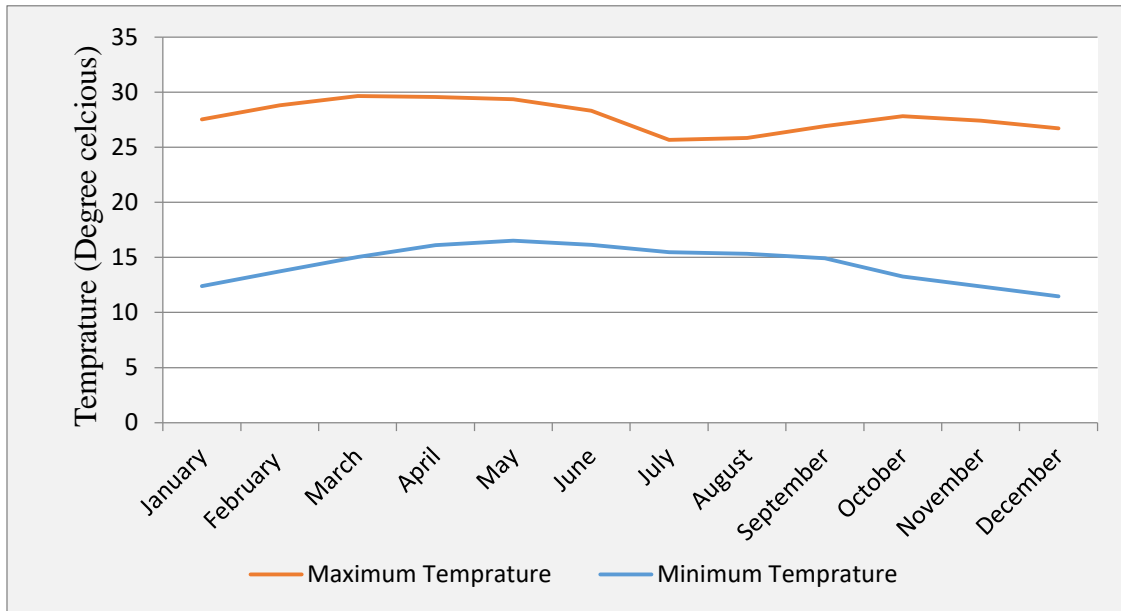


Figure 1.4: Monthly average of 15 years minimum and maximum temperature of Ziway station (Source: Ethiopian National Meteorology Agency, 2003-2017).

The CRV of Ethiopia has different soil types with varied infiltration and runoff potential. Coarse textured soils having high infiltration rates are dominantly found in the eastern and western highlands and around the lakes in the valley floors. Medium textured soils with moderate infiltration rates dominate the eastern and western mid altitudes. Fine textured black soils (vertisols) with low infiltration dominates the foothills of western highlands and some areas in the central part of eastern CRV (Getnet *et al.*, 2014).

Acacia woodlands and savannas are the dominant vegetation types in the CRV. The rate of deforestation is growing every year due to poor land management systems and conversion of naturally vegetated areas to agricultural land as a result of rapidly growing population (Meshesha *et al.*, 2012). Abundant livestock population has played its part in the loss of vegetation and grass cover through overgrazing of range lands (Ayenew, 2007).

Central rift valley area encompasses a network of rivers and lakes, which are subdivided into seven connected sub-basins such as Ketar, Ziway, Meki, Bulbula, Langano, Horakelo and Abyata. The Meki and Ketar sub-basins drain to Lake Zeway through Meki and Ketar rivers respectively. Lake Zeway has natural overflow through the Bulbula River to Lake Abyata. Bulbula connects Lake Abyata to Lake Zeway and it also collects direct runoff from its basin (Getnet *et al.*, 2014). Water abstraction for irrigation has increased considerably in the CRV area. Irrigation development in the area is curbed to the Lake Zeway sub-basin along Lake Zeway and between the discharge gauging stations of Meki, Ketar and Bulbula Rivers. The diversity of landscapes and ecosystems comprise unique biodiversity-rich wetlands (Jansen *et al.*, 2007). The lakes are highly productive, harbouring an indigenous population of edible fish and support a wide variety of other aquatic and wild life. They are globally significant freshwater ecosystems containing important areas of both terrestrial and aquatic biological diversity, and most are becoming degraded as a result of human activities (Lake Ziway and their influent rivers are used for irrigation, flower industry, soda abstraction, fish farming, domestic use and recreation) (Ayenew, 2007). The CRV is a closed basin, thus, relatively small changes in land use and ecosystem has significant adverse effect on the ecosystem (Ayenew, 2007).

Agricultural production and its related activities are the major base that sustains the CRV economy; industry and service sectors have low contribution for the economy. The dominant farming system in the area is small scale, rain-fed and low yielding cereal crop production. Currently, farmers have been forced to practice multiple cropping (agricultural diversification) on a small holding and convert marginal and rangelands into farms (agricultural extensification) due to the pressure from food deficit resulting from low yielding. The main crops under such cultivation include maize, sorghum and Teff. Crops like haricot bean are produced for consumption and commodity (Bekele, Belay, Legesse, & Lemma (2010). Barely, lentils, horse bean, chickpea and field pea are also crops that are growing in the area. Most of the cultivated land found in the valley floor.

Concerning irrigation farming system in CRV, there are four kinds of irrigation production systems categorized based on the type of ownership, farm size and production as closed vegetable and flower production (greenhouse production), open field vegetable and fruit production on state farms, open field vegetable, fruit production on private farms and open field smallholder vegetable and fruit production systems (Hengsdijk and Jansen, 2006). The floriculture farming, owned

primarily by large scale foreigners, produces different kinds of cut flowers for export markets. It uses water for irrigation from the surrounding lakes; the most important source of the water is Lake Ziway. The horticulture farming is a diversification of agricultural production by local smallholding farmers from mono-cropping of maize to multiple cropping and from rain-fed to irrigation farming, with increased frequency of production on a specific smallholding two to three times per year. The major horticultural crops cultivated by the small scale irrigation system include potato, white and red onion, cabbage, beetroot, carrot, hot pepper, tomato, broccoli, haricot beans, sweet pepper and lettuce for on-farm income generation and consumption (Hengsdijk and Jansen, 2006).

1.7 General methodology and approaches

1.7.1 Research design

The research design of this study is a cross-sectional survey employing both quantitative and qualitative mixed approaches. Cross-sectional is less time consuming compared to the longitudinal studies. This design has an advantage for the investigation of population-wide features at a single point in time. However, the cross-sectional approach has demerit for exploring the developmental stage of subjects over the period (Cohen *et al.*, 2000). Researchers are expected to explain their philosophical world view to justify the rationale of selecting a specific research design. The next paragraph presents the researcher's world view on the rationale of selecting a mixed research approach, which is termed as pragmatism philosophical paradigm.

A research methodology is a philosophy that guide the overall research and use to indicate the philosophical assumptions that justify the use of particular methods (Dawson, 2007). According to Pathirage *et al.* (2008), the investigation in research is guided by research philosophy having the assumptions of ontological, axiological, and epistemological. The idea of ontology is concerning about the assumptions of reality, the epistemology is related to the assumptions on how to undertake research, and axiology depends on the assumptions of value system. The understanding of nature depending on such assumptions is important to develop research philosophy, which later guides the choice of the right research methods. Crotty (1998) suggests that an interrelationship exists between the philosophical stance adopted by the researcher, the methodology and methods used, and the researcher's world view. Easterby-Smith *et al.* (2012)

argue that failure to think through philosophical issues can seriously affect the quality of research, which is central to the notion of research design.

Researchers' mental models concerning reasoning are important to design the research approach. These mental models are called paradigms. The difference between quantitative and qualitative research is quite fundamental, leading people to argue about 'paradigm wars' in research. This idea is linked to the different underlying philosophies and world views of researchers in the two 'Paradigms' (Creswell, 2009). Thus, quantitative research is described as being 'realist', 'positivist', or experimental, while the worldview underlying qualitative research is viewed as 'subjectivist', post-positivism, or constructivist.

Positivism claims that science or knowledge creation should be restricted to what can be observed and measured; the role of research is to uncover an existing reality (Bhattacharjee, 2012). The researcher needs to be detached from the research as much as possible and use methods that maximize objectivity. According to positivism the world works based on fixed laws of cause and effect. Scientific thinking is used to test theories about these laws, and either reject or provisionally accept them. Later on, frustration with the extreme and strict empirical nature of positivist philosophy led to the development of post-positivism during the mid-late 20th century. Post-positivists view science as not certain but probabilistic and social science focuses on confidence-how much can we rely on our findings. As to Robson (2002) researchers will never be able to uncover the reality through research. The world is considered as a result of our mind setup rather than being an objective reality based on the idea of the subjectivists. Social constructionism stems from the view that reality is not objective and exterior, but socially constructed and given meaning by people (Easterby-Smith *et al.*, 2012; Robson, 2002).

According to Tashakkori & Teddlie (1998), taking polarization stand on extreme subjectivist or positivism approach is problematic. Thus, the perspective of pragmatism has got acceptance by a few scholars who argued with the possibility of mixing quantitative and qualitative approaches in single research (Kelemen and Rumens, 2012). Pragmatism has seen by some to provide an epistemological justification for mixing approaches and methods. In some cases, the use of a mixed approach is necessary rather than an option (Onwuegbuzie *et al.*, 2009). Easterby-Smith *et*

al. (2012) and Remenyi *et al.* (1998) emphasized the significance of looking at positivism and social construction as related ideas in a dialectical interaction. This helps in seeing research methods as providing a set of tools in which the researcher may select the appropriate tool. Many researchers, both quantitative and qualitative, take a pragmatist approach to research (Creswell, 2009; Dawson, 2007; Tashakkori & Teddlie, 1998).

Methodological pluralism is an excellent starting point for empirical research (Carter and Caroline, 2003). In the view of Bryman (2016) methodological pluralism or eclecticism serves the role of initiation in cases when contradiction and fresh perspective emerge in the study. Mixed methods research is broadly accepted to indicate researches that integrate both qualitative and quantitative data within a single study (Wisdom *et al.*, 2012). Scammon *et al.* (2013) supported strongly on the advantages of using mixed research methods using both quantitative and qualitative data in a single research investigation. Creswell (2009) and Knox (2004) explained that both methods have strengths and weaknesses; when both used together, these methods can be complementary. The mixed research method includes the application of quantitative and qualitative data in single research; the data can be collected sequentially or concurrently depending on the nature of the research (Tashakkori & Teddlie, 2010).

In using a mixed research design, there are three methods to apply this design in research. The first is concurrent or parallel mixed methods design, which is useful to compare the quantitative and qualitative analysis keeping the balance for types of data. The second method is exploratory sequential design in which the researcher first collects qualitative data and then collect quantitative data. This design gives more focus on collecting and analyzing qualitative data than quantitative data. The third mixed method design is the explanatory sequential design whereby the researcher first collects quantitative data and then qualitative data to elaborate on the quantitative result. The current research applied this third mixed-method research design. The quantitative data are important to reveal generalizable information for a large group of people. In contrast, qualitative data provides meaning and context regarding the people and environments of the study.

As Bryman (2016) quantitative methods always rest upon a qualitative conceptual framework. The researchers' decision on mixed-method mainly depends on the benefit of using both techniques

rather than choosing a single method. In the current study, a mixed research design is preferred as it allows the collection and analysis of diverse and complex data using both qualitative and quantitative techniques. If either qualitative or quantitative method was independently employed in this research, it would be difficult to address all the specific objectives of the study. In the research, the qualitative data that were collected using focus group discussion, household interview, and key informant interview were used to validate the quantitative data collected using household survey and laboratory analysis.

Thus, employing a mixed-method research design allows one to simultaneously answer confirmatory and exploratory questions, however, qualitative and quantitative methods independently cannot address these questions at a time. Using mixed-method design is important to expand the scope and breadth of the study by triangulating both types of data in the research. Some of the research questions such as the salinity status of irrigation water and the soil were answered mainly using quantitative data. However, qualitative data collected from farmers' in-depth interview and experts' key informant interviews were used in explaining how SSI practices affect the salinity status of the soil in irrigated farmlands. Quantitative data were dominantly used to investigate the determinants of farm households' decision to participate in SSI and the impacts of SSI on household income. On the other hand, both quantitative and qualitative information were used to analyze the effects of irrigation on livelihood and the constraints that hinder the enhancement of SSI in the study sites.

1.7.2 Sampling design

Sampling technique for quantitative data

The current study used a multi-stage sampling technique applying both random and purposive sampling techniques to select sample households for collecting the household survey data. In the first stage, purposive sampling was used to select the two study districts (Woredas) (Adami Tulu Jido Kombulcha (ATJK) and Zeway Dugda) among 11 districts in the zone due to their high vulnerability for drought, which makes irrigation agriculture a necessity than an option in these districts. As can be seen in the findings of Gizachew & Shimelis (2014), these districts are among the worst hit by drought in the CRV area (as shown in figure 1.5) and presented in the problem statement section. Furthermore, due to the effect of drought these two districts characterized by

food and nutrition insecurity, and safety net dependency. For instance, in 2016/17, there were 136329 and 58,000 people who received relief assistance food aid in ATJK and Zeway Dugda districts respectively (ATJK and Zeway Dugda districts' Disaster Risk Management Office (DRMO), 2017).

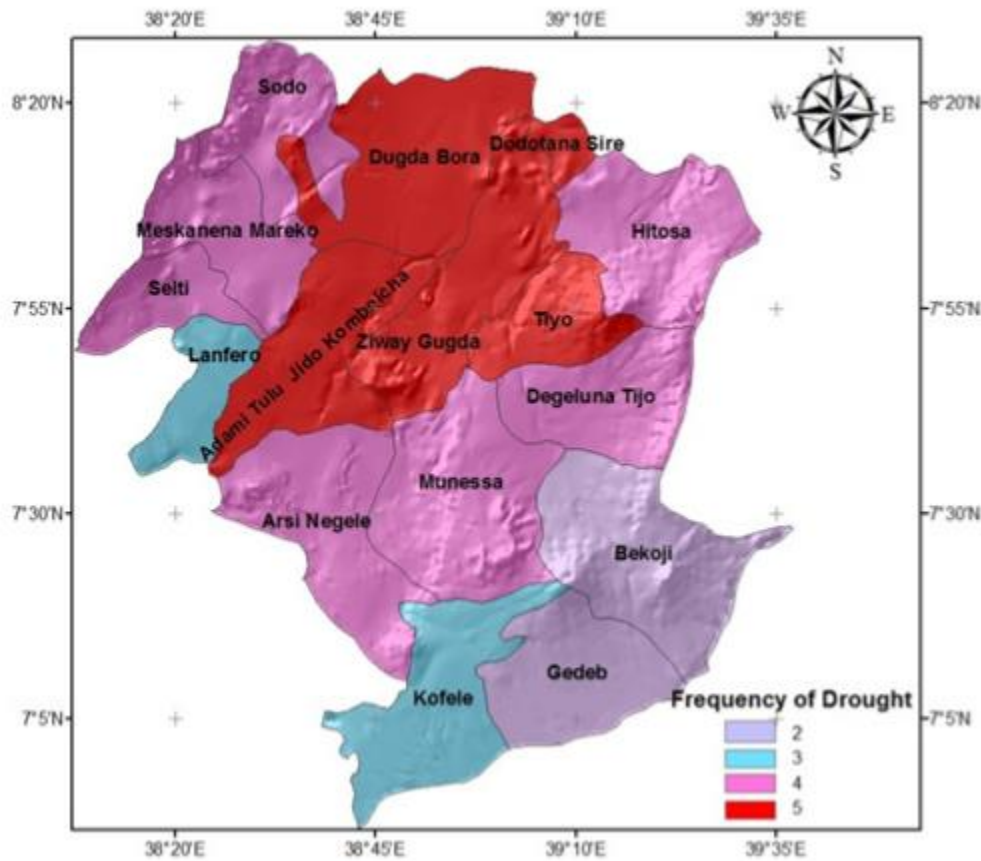


Figure 1.5: Drought frequency map of Central Rift Valley of Ethiopia (Source: Gizachew & Shimelis, 2014).

In the second stage, Kebeles¹ that have both irrigation user and non-user were identified with the support of development agents. Then, using simple random sampling techniques Bochessa, Dodicha, and Gulba Aluto *Kebeles* were selected as representative *Kebeles* from ATJK. Shelad and Arata Chufa *Kebeles* were selected from Zeway Dugda. The list of non-irrigators and irrigators

¹ Smallest administrative unit

were collected from the district agriculture and irrigation offices. The sample households (HHs) were selected using a stratified systematic proportional sampling technique stratifying the households based on their sex, and irrigation users and non-users and type of irrigation. The total number of households of the two districts of the year 2007E.C (2014/15) was obtained from the district agriculture office, thus, the total population of Zeway Dugda is 27,970 and ATJK is 26,982 and it is 54,982 summed up. Based on this source data the total household of the five *kebeles* is calculated following Kothari (2004) at 95% confidence level with standard variate) value of 1.96, sample proportion (p) value of 0.5, and a 5% of the level of precision() are assumed.

$$n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2(N - 1) + z^2 \cdot p \cdot q}$$

n is sample population

N is total population

p is sample proportion and $q = 1 - p$

e is level of precision (acceptable sampling error)

z^2 is the value of the standard variant with the given confidence level.

Based on the formula, the calculated minimum sample size was 384. 15% of this sample size was added to the sample size as a contingency to accommodate incomplete questionnaires. Hence, data was collected from 442 Household heads (HHHs). Finally, 11 incomplete questionnaires were found, which were not included in the analysis. Hence, 431 respondents with complete questionnaires were included in the final analysis. Then, these total 431 households are proportionally allocated based the sample size of the five *kebeles* stratifying using irrigation users and non-users and based on the sex of the household head as shown in Table 1.1. The total number of non-irrigation user farmers in the five *kebeles* 3739, however, in this research 1471 non-irrigation user farm households are considered purposely by excluding households having no access to water resources to participate in irrigation. Otherwise, if all the 3739 are considered as a sampling frame for non-irrigation users it affects the proportionality and has no relevance to study about irrigation use in the absence of no access to water. Mulu (2016) used similar purposive techniques to minimize disproportionality in the case of biogas technology adoption. Finally, after

the sample households from each category is determined (Table 1.1), a simple random sampling technique is used to select the participant household to fill the survey questionnaire.

Table 1.1 Sampling strategy for quantitative data (household survey)

Districts	Kebeles	Total irrigation user household size	Sample irrigation user household size		Total non-irrigation user household	Sample non-irrigation user household size		Total	
			Male headed	Female headed		Male headed	Female headed		
ATJK	Bochessa	322	37	20	40	354	28	13	41
	Dodicha	280	41	8	32	374	29	11	40
	Gulba Aluto	278	32	16	53	184	15	6	21
Zeway Dugda	Arata Chufa	324	49	8	55	169	20	5	25
	Shelad	277	39	9	79	275	32	13	45
Total		1481	198	61	259	1471	124	48	172

Sampling strategy for qualitative data

Purposive sampling techniques such as snowballing and convenience sampling techniques were used to select participants for Focus Group Discussion (FGD) and household interview and key informant interview based on a judgmental basis until a saturation point is reached. In a single FGD 8-10 people are participated. The composition of the participants consider male head, female heads, elderly and young, irrigation user and non-user. The distribution of the respondents for FGD and interview are shown in Table 1.2.

Table 1.2: Participants in qualitative data collection (number and type)

Districts	Kebeles	Mixed group FGD	FGD with irrigators	Household interview		Key informant interview		
				MHH	FHH	Bureau head (agriculture & Irrigation)	Experts (Irrigation and development agents(DA ²))	Chairperson of local water user association committee
ATJK	<i>Bochessa</i>	2	3	5	4	2	2	3
	<i>Dodicha</i>	1	2	5	7	2	2	2
	Gulba Aluto	1	2	4	4	2	2	2
Zeway Dugda	Arata	2	2	4	5	2	2	3
	Chufa Shelad	2	2	4	5	2	2	4
Total		8	11	22	25	10	10	14

1.7.3 Data sources and methods of data collection

In this study, both quantitative and qualitative data types were used to get adequate and reliable data to explore the environmental and socio-economic impacts of small scale irrigation. The nature of the study by itself demands the use of both quantitative and qualitative data because some of the issues need generalizable information while some others need elaboration and meaning to provide contexts of the given environmental setting. Many authors such as (Bryman, 2016; Wisdom *et al.*, 2012; Scammon *et al.*, 2013, and others) advocate this approach. For instance, Scammon *et al.* (2013) noted that combining qualitative and quantitative data collection capitalizes on the strengths of both qualitative and quantitative research, whilst ameliorating their weaknesses to provide an integrated comprehensive understanding of the topic under investigation. Accordingly, in the current study, both qualitative and quantitative data were collected from primary and secondary sources and discussed below.

Primary data collection Methods: Field data were collected from February 2017 to May 2017 considering the immediate past cropping season of 2015/2016 by helping farmers to recall their

² Government employees who provide technical support on agriculture and natural resources management working at Kebele level

agricultural activities. The primary data were collected using the following methods and instruments.

1) Household survey: structured survey questionnaire was prepared based on a review of the literature and preliminary field visit and discussion with experts. This is the most important tool to collect cross-sectional quantitative and other necessary open-ended data. The household heads (HHHs) were interviewed to fill the survey questionnaire. The contents of the questionnaire include questions on farmers' personal and plot-level attributes (age, education, gender, family size, livestock holding, land ownership type, type of occupation, land size owned, off-farm work, and amount of income from different sources). To evaluate the impact of SSI on the annual gross income of the household, all sources of income such as agricultural (cropping and livestock) incomes and non-agricultural (off-farm and other) incomes were included. Questions were also included on farmers' access to supportive institutions (credit and contact with extension agents). The major plot-level characteristics (soil fertility, accessibility of water sources, and distance from the plot to the district market, use of inputs and agricultural outputs) were also included in the questionnaire. The household survey question has also questions to examine the households' wealth status based on community-based wealth indicators, which were determined based on preliminary assessment and literature (Duguma, 2015). Furthermore, some survey items are exclusively used to collect data from irrigation user farm households. These items target to gather data concerning the features of SSI farming, benefits of SSI on farming household livelihood, negative effects of SSI on environmental resources, society, and the household economy, and the challenges that irrigators encountered while working in irrigation farming. The survey questionnaire also contains items to collect data from irrigation user farming households about soil salinity problems, sources of salinity, effects of salinity, and soil salinity ameliorative measures employed by irrigators.

2) Focus group discussion (FGD): Eight to ten farmers participated in a single FGD. The FGDs were conducted classified into two categories based on the type of group composition. The first FGD category includes mixed group (irrigation users and non-users having both males headed and female-headed households), and the second category was held with irrigation user farmers only having both female and male-headed households in the group. The FGD guide (checklist) which was prepared for the mixed group includes some general issues about the commonalities' view

regarding climate variability, rainfall pattern and its variability, and drought occurrence in their living environment. The guide also includes questions to capture the communities' views about the significance of SSI intervention for farming households. Furthermore, the guide has issues that target to generate data regarding farmers' view comparing the livelihood of irrigation user and non-user farmers in their surroundings. This is important to understand the contribution of irrigation looking in the mirror of irrigation users and non-users from the farmers' own words based on their locally used wealth indicators. Besides, this part of the FGD guide has some questions about the factors that affect the decision of farmers to work in irrigation farming.

The FGD guide with irrigation user farmers includes discussion points about the effects of irrigation on livelihood, food consumption, agricultural yield amount, and type of production (cereals, vegetables, and fruits), income, and environmental resources. Farmers were asked whether the effects are positive or negative (including issues whether there are adverse effects on water, land, biodiversity, crop pests, animal, and human health problems due to irrigation farming in their area if any). In this category of the FGD much attention was also given on the effects of irrigation farming on soil with particular attention to exploring the effects on soil salinity development, sources of salinity, effects of salinity, and the measures taken by farmers to mitigate the problem of salinity in their farm plot. Irrigation user farmers were asked to discuss the situation of soil quality comparing their irrigated and rain-fed plots. Also, the FGD guide in this category has questions to obtain the community view about the major challenges that constrained irrigation farming and the economic benefits that farmers expect to gain from it. The other important issue included in this FGD category is the level of farmers' participation irrigation scheme management, communities' view regarding women participation in irrigation and being a member of the local-level water user association committee, and the performance of the local level water user association committee. We believe that the concern of the resource users is critically important to work towards improving the performance of SSI, so that, the FGD guide include issues that allow farmers to suggest their remarks for future improvement of the SSI farming in their area.

3) Interview: A semi-structured interview is the most common method to collect qualitative data as it allows the researcher to know the specific information that can be compared and contrasted with data obtained by other tools (Dawson, 2007). In this research, semi-structured interview

checklists were used to collect data from two groups such as household interviews and key informant interviews. The household interview was undertaken with irrigation user farmers including both male-headed and female-headed households.

The household interviews are the main sources of data for gathering information on farmers' participation in irrigation scheme management and the challenges and opportunities of SSI farming from the perspective of gender. Some of the questions are used in common for both male and female household heads such as issues related to irrigation water-based conflict, irrigation water distribution, effects of irrigation on soil, factors affecting the sustainability of irrigation scheme, equity in participation and sharing benefits from irrigation, socio-economic and environmental effects of irrigation. Accordingly, the interview guide with male household heads includes questions to examine the level of farmers' participation in irrigation scheme management, existing challenges in the participation process, the views of irrigators about the performance of local level WUAs committee, and the communities' view on women participation in irrigation. The interview guide with female household heads is used to gather data about existing challenges and opportunities concerning gender contexts. It contains issues like the state of women participation in irrigation, women participation in the decision-making process in the local level WUAs and the like. The household interview guide includes many issues that are important to complement and verify the quantitative data.

Key informant interviews (KII) were conducted with officials and experts working at the district level (irrigation experts and agronomist), head of bureaus of (irrigation, and agriculture and natural resources) and with agricultural development agents. A single interview guide was used to conduct KII with district-level experts, bureau heads, and agricultural development agents. The contents of the KII guide includes issues about the trends in the development and expansion of SSI in the districts, major challenges of irrigation development in the area, effects of irrigation expansion in the community, types of irrigation practices, irrigation water usage mechanism of the farmers, conflicts related to water use, state of the sustainability of SSIS and the like. KII was also conducted with agricultural development chairperson of local level WUAs committee. The interview guide contains issues about forms of farmers' participation in irrigation scheme

management, women participation in decision making, challenges the WUAs faced in managing the SSIS activities, and the like.

Procedures of field data collection: DAs were considered as appropriate data collector and supervisors as they have contact with farmers and have familiarity with the area and about the existing agricultural practices and even about the norm of the community. The DAs who speak both Amharic and Afan Oromo were selected in consultation with ATJK and Zeway Dugda district irrigation experts because in some selected Kebeles the language skill of the household varies as some speak only Amharic, others only Afan Oromo and some others both. Training was given for three days in each of the districts for data collectors and supervisors for household survey. Then, the data collection process was done under the close supervision of the researcher.

The FGD and interviews were conducted by the researcher using Afan Oromo translator (a PhD fellow at the Center for Environment and Development studies) depending on the language skill of the participants. The data were recorded using an audio recorder and later transcribed and translated into English.

4) Collection of soil and water samples: The main purpose of this data set is to determine the effect of irrigation on soil resources in irrigated farm plots and to examine whether there is an association in soil salinity development with the irrigation water sources. This data is also important to verify the data collected by other methods. The detailed methods of sample collection are presented in chapter 3.

Secondary data collection methods

The secondary data were collected from various published books and research articles and unpublished sources. Important documents were collected from Zeway Dugda and ATJK districts offices of agriculture and natural resources management, irrigation office, disaster and risk management office (data on drought-induced vulnerability of the households), water resources office, agronomy office and others about the development of SSI in the two districts, its impacts and the areas vulnerability to rainfall variability and chronic drought. Government policy and program documents were also important secondary sources of data. The temperature and

precipitation data for 2003-2017 were extracted from the National Meteorological Agency Zeway station data.

Pilot survey: Before the actual data collection task, a pilot survey was conducted at Haleku SSIS which is found at ATJK district. 35 household surveys were conducted from both irrigation users and non-users. Based on the pilot some of the questions are canceled, some important questions are added to the household survey questionnaire items. The survey tool is properly revised based on the input from the pilot survey.

1.7.4 Methods of data analysis

The quantitative data were analyzed using SPSS, EXCEL, and STATA software. The qualitative data were analyzed using Nvivo software. The detail on the data analysis techniques is presented in each of the chapters.

1.8 Structure of the thesis

This paper contains five chapters. The first chapter comprises an introduction, includes the background of the study, statement of the problem, objectives, research questions, methodology of the research. The second chapter presents the determinant of farmers' participation in irrigation and, effects of irrigation on HH income and its implication on livelihood sustainability. The third chapter deals with the effects of irrigation on soil based on soil and water laboratory analysis. Chapter four has the research finding on the features, benefits, challenges, and sustainability of livelihoods with irrigation intervention. The fifth chapter presents the synthesis of the study, policy implications, and future research areas.

Chapter 2: Farmers' participation in small scale irrigation and its effect on household income in the drought prone central rift valley of Ethiopia

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Abstract

Smallholder rainfed agriculture is the mainstay for the majority of the population in Ethiopia. However, its performance is very poor, particularly in drought-prone areas. Hence, small scale irrigation has been introduced to averse the negative effects of climate variability. This research aims to examine the determinants of farmers' decision to work (decision to invest) in irrigation, the effects of irrigation on income and its implication on rural livelihood sustainability. Data were collected using a household survey questionnaire, focus group discussions and interviews. Descriptive statistics and the Heckman two-step model were used to analyze the data. Farmers' decision to participate in irrigation is affected by many interdependent factors. Among the factors road and market access needs immediate attention by the government and other actors in irrigation development particularly these problems are severe in Zeway Dugda district compared to ATJK district in which the schemes found relatively near to the district town Batu (Zeway). Participation in irrigation significantly and positively affects the amount of household income. However, the contribution of irrigation on household income has a limited role to support the sustainability of livelihood in the time of chronic drought in which irrigators were in food aid like non-irrigators. Creating market access, credit provision, better extension service, introducing gender-friendly irrigation technology, and expanding irrigation command area needs policy priority to sustain the economic benefit of irrigation.

Keywords: Participation, small scale irrigation, determinants, household, Central Rift Valley.

2.1 Introduction

Agriculture is the dominant form of economic activity worldwide and it also provides different ecosystem services. In SSA, agriculture is the dominant livelihood system for the majority of the population (Shiferaw *et al.*, 2014), yet, drought is a recurring reality (Gautam, 2006). Smallholder farmers in developing countries are predominantly affected by the impacts of global climate change due to their high vulnerability as a result of mainly located in the tropics and due to many interrelated factors (IPCC, 2014; Komba & Muchapondwa, 2012; Mertz *et al.*, 2009). Hellmuth, Osgood, Hess, Moorhead, & Bhojwani (2009) emphasized that the nature of climate variability and unpredictability as the major risk factors that hinder options and limit livelihood development of millions of poor people in SSA. According to Scheffran, Marmer, & Sow (2012) drought has caused depletion of assets, environmental degradation, impoverishment, unemployment, and forced migration in Africa during the past five decades. These same authors also noted that the frequency of droughts has increased steadily in East Africa, where Ethiopia is not exceptional. Future climate projection which was undertaken by IPCC (2007) revealed that the area suitable for agriculture, the length of growing seasons, and yield potential are expected to decrease particularly in the margins of arid and semi-arid parts of Africa.

The rainfall pattern in most regions of Ethiopia is not conducive to crop production due to its erratic nature causing crop failure and production decline (Araya & Stroosnijder, 2011; Yihun, 2015). Prolonged and recurrent drought occurrence adversely affects the livelihood of the agricultural communities and the Ethiopian economy as a whole (Awulachew, 2019). The negative effects of climate variability on the livelihood of people who are dependent on agriculture are diverse, for example, Feleke, Assefa & Zeleke (2019) and Yihun (2015) revealed that high-temperature results in the reduction of agricultural productivity while it creates a conducive situation for weed and pest proliferation. The occurrences of erratic rainfall and chronic drought emphasized the need for irrigation in Africa in which Ethiopia is not exceptional (Adeoti, 2008; Araya and Stroosnijder, 2011). Ethiopia has abundant water resources and quoted as ‘Ethiopia is the water tower of East Africa’. Nevertheless, the big challenge of agricultural development in the country is rainfall variability on the spatial, temporal, and inter-annual basis (Araya and Stroosnijder, 2011). Thus, irrigation farming is not optional particularly for smallholder farmers

living under the challenges of climate variability, which is the common problem in the CRV of Ethiopia. In line with this, some scholars documented that smallholder farmers in the CRV area stretch their hands for food aid from the government PSNP in the time of chronic drought (Ayenew, 2007; Jansen *et al.*, 2007; Pascual-Ferrer *et al.*, 2014). According to Awulachew *et al.* (2005) and Feleke *et al.* (2019), SSI technologies have been introduced in the area to overcome the deep-rooted problems of food insecurity and poverty that are aggravated by climate variability.

However, simple provision of irrigation technology cannot lead to the intended result in improving agricultural productivity while coping up with climate variability at the same time without the full participation of the local farmers. In relation to this many factors can determine the full scale of farmers' decision to participate in SSI. According to Sharaunga & Mudhara (2018), the success of a communal SSIS is highly affected by the collaboration and communal participation of the community in the irrigation command area to enhance equitable benefits from investments in SSI. Mwendera and Chilonda (2013) emphasized that farmers' participation in different irrigation management practices has an important role to lead to sustainable agricultural productivity. Furthermore, water scarcity has been among the major challenges of irrigation farming due to population growth, climate change and lack of access to water services (Namara *et al.*, 2010; Steduto *et al.*, 2017; UNEP, 2012; Vrochidou, Tsanis, Grillakis, & Koutroulis, 2013). Similarly, smallholder irrigators in CRV of Ethiopia have been facing water scarcity problems, which found to be the main hindering factor to run irrigation on a sustainable basis. In this regard, the participation of the water user association (WUA) members in irrigation scheme management play a critical role in the sustainability of irrigation farming.

Sharaunga & Mudhara (2018) noted that poor participation in irrigation scheme management has been a challenge in many developing countries leading to underperformance of irrigation schemes. Therefore, it is imperative to understand the factors that influence the levels of farmers' participation in irrigation farming to recommend better policy and institutional arrangement options for WUAs in the CRV of Ethiopia. Therefore, the first aim of this study is to identify the determinants of farmers' decision to work in irrigation and analyze the types of farmers' participation in irrigation farming. This research is different from previous investigations, such as Abebe (2017), who only investigates determinants of farmers' decisions to participate in irrigation.

But, in this research we argued that simple membership in WUAs cannot lead to improved irrigation performance without the full participation of members in the irrigation farming. Hence, analyzing the types of farmers' participation is the important aim of this investigation. The second aim of this research is to examine the effects of SSI on household (HH) income and its implication on the sustainability of rural livelihood development. The result of the study can give valuable information for policymakers and development practitioners to make better policy intervention either to expand new SSIS or upgrade the existing schemes in the area or other parts of the country having similar biophysical and socio-economic conditions with CRV.

2.2 Conceptual framework and variables

Hardin (1968) conceptualize the theory of 'tragedy of the commons', which states that participation in collective action is influenced by the natural selfishness of humans and the rational self-interest against the interest of the common good. The assumption of Hardin's model postulates the inability of individuals to cooperate and the problem of 'free-riders' as affecting participation (Hardin, 1968). The problem of institutional failure and lack of compliance to rules governing schemes results in poor participation, which consequently leads to scheme de-generation into open access resources as defined by the 'tragedy of the commons' (Sharaunga & Mudhara, 2018). Sharaunga & Mudhara (2018) identified several factors that affect farmers' decision to participate in irrigation including economic, demographic characteristics, natural/ecological, psychological, and policy-related such as institutional/managerial or administrative factors.

The conceptual framework of the study is presented in Figure 2.1 and it is designed to explore determinates of farmers' participation in SSI and the factors affecting HHs' income obtained from irrigation. Economic factors play a significant role in affecting the decision of farmers to participate in a certain program developing expectation in gaining an economic benefit or generating revenue from the participation for example, in irrigation farming (Kim & Khiev, 2007). Besides, the cost of labor, access to credit facilities, cost of the farm operation, and costs for other inputs of irrigation are economic factors that affect farmers' decision to participate in irrigation (Maleza and Nishimura, 2007). Household demographic characteristics such as household size

(Alam *et al.*, 2012), level of education (Shamiyulla, 2010), and age (Sharaunga *et al.*, 2013) are also factors that determine the decision of farmers to participate in irrigation.

The ecological or natural factors for instance having land security and higher farmland size positively affects farmers' decision to participate in irrigation (Arun *et al.*, 2012; Nakano and Otsuka, 2011). Efficient and reliable water supply also creates incentives for participation in irrigation infrastructure maintenance (Maleza & Nishimura, 2007). Social capital is another important determinant of individuals' participation in community programs (Coulibaly-Lingani *et al.*, 2011). Cooperation between and active participation by local beneficiaries through their community institutions determines the success of outcomes depending on the trust, norms, and networks, which tend to be self-reinforcing. According to Poteete and Welch (2004), farmers' participation in irrigation is affected by institutions as it determines the interest and cooperation of collective action. SSIS are common-pool resources in which the sustainability of the schemes is determined by the participation of the users. Hence, this research aims to identify the determinants of farmers' decision to participate in irrigation.

Furthermore, HHs' income considered to be among the key factors that can affect the sustainability of the livelihood of the communities in many ways. If the income of the HH is good, he/she can invest in different production enhancing agricultural technologies, can diversify livelihood strategies, and could invest in environmental conservation and rehabilitation strategies. Therefore, this study investigated the factors that affect the amount of HH income obtained from working in irrigation. The study also analyze the effects of SSI on HHs' income and its implication on the sustainability of rural livelihood development.

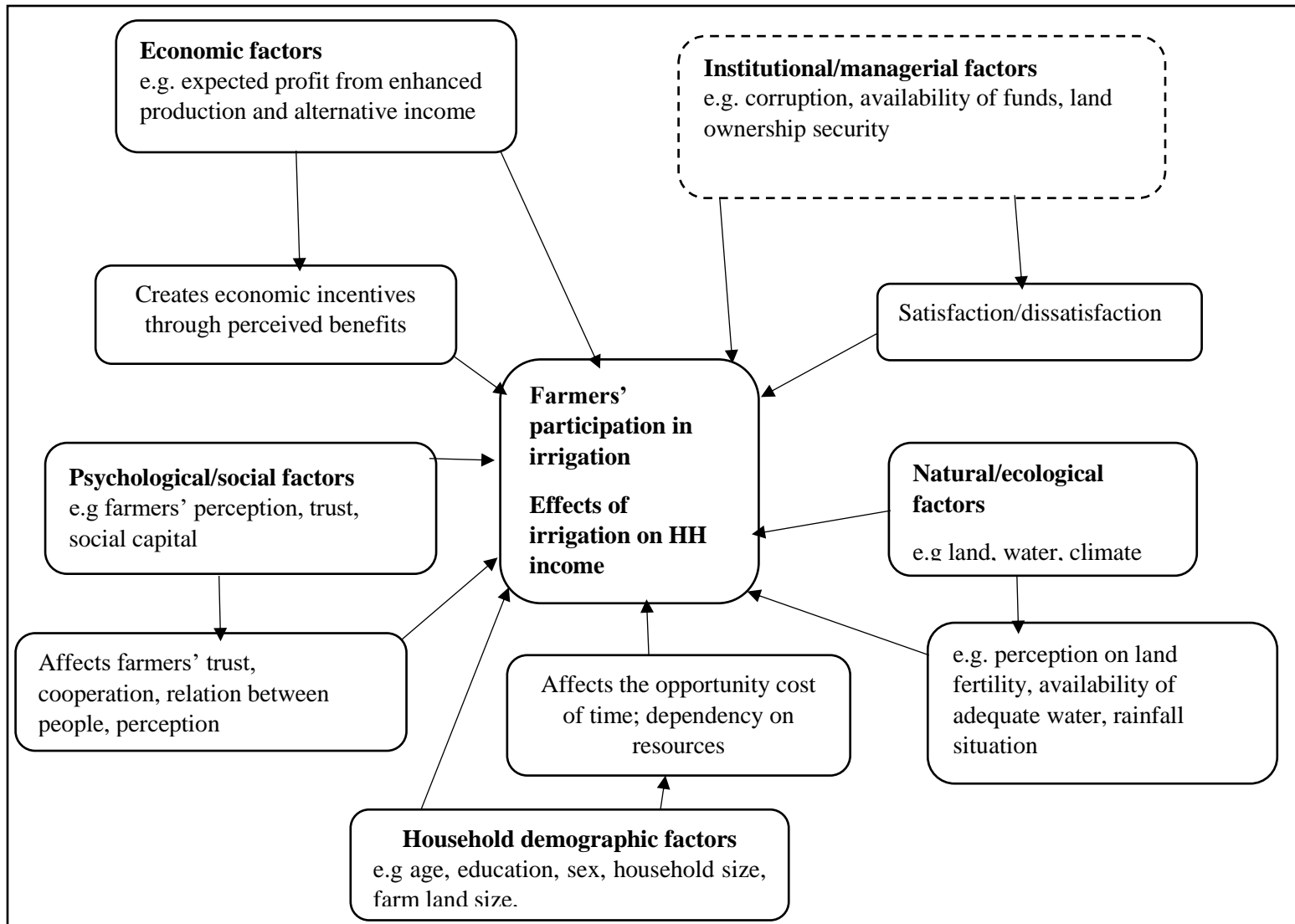


Figure 2.1: Conceptual framework (Sources: Own construction based on literature (Hirko *et al.*, 2018; Sinyolo *et al.*, 2014; Yami, 2013).

Table 2.1: Definition of dependent and independent variables on determinants of HH participation in SSI

Dependent Variable	Definition and measurement				
HHs' decision	HH decision to participate in irrigation (dummy 0=user, 1=non-user)				
Independent variables	Definition and measurement	Variable type	Hypothesized relationship	Identified relationships in the previous studies	
				Positive	Negative
AGE	Age of the HHH (in years)	Continuous	Positive	(Bacha <i>et al.</i> , 2011; Haji <i>et al.</i> , 2013)	Sinyolo <i>et al.</i> (2014)
AGESQ	Age of the HHH square	Continuous	Negative		
FAMSIZAE	Family size in adult equivalent (in number)	Continuous	Positive		Tesfaye <i>et al.</i> (2008)
FAMSIZAESQ	Family size in adult equivalent square	Continuous	Negative		Tesfaye <i>et al.</i> (2008)
DEPRAT	Dependency ratio(in number)	Continuous	Negative		Bacha <i>et al.</i> (2011)
TCULAND	Total cultivated land (hectar)	Continuous	Positive	Legesse <i>et al.</i> (2018)	Sinyolo <i>et al.</i> (2014)
TLU	Total livestock holding of the HH (in TLU)	Continuous	Positive	Asayehegn (2012); Tesfaye <i>et al.</i> (2008)	
EDUC	Educational level of the HHH (in years)	Continuous	Positive	Ogunniyi <i>et al.</i> (2018); Legesse <i>et al.</i> (2018)	
IRRLAND	Access to irrigable land(yes=0, otherwise=1)	Dummy	Positive	Tesfaye <i>et al.</i> (2008)	
DISMARK	Distance from farm plot to the district market(in walking hours)	Continuous	Negative		Sinyolo <i>et al.</i> (2014)
SEX	Sex of the HHH (male=0, otherwise=1)	Dummy	Negative	Bacha <i>et al.</i> (2011); Legesse <i>et al.</i> (2018)	
CREDIT	Credit service (0=Yes, otherwise=1)	Dummy	Positive	Ogunniyi <i>et al.</i> (2018); Sinyolo <i>et al.</i> (2014)	Tesfaye <i>et al.</i> 2008
EXTENSION	Extension service (Yes=0, otherwise=1)	Dummy	Positive	Abebe (2017)	Gebremariam & Ghosal (2016)

PERCEP	Farmers' perception on land fertility (fertile=0,Otherwise=1)	Dummy	Positive	Sinyolo <i>et al.</i> (2014); Tesfaye <i>et al.</i> (2008)
TRAINING	Participation on farming related training (yes=1, otherwise=0)	Dummy	Positive	Abebe (2017); Sinyolo <i>et al.</i> (2014)

Table 2.2: Definition of dependent and independent variables on determinants of HH gross income

Dependent Variable	Definition and measurement				
HH annual income	HH gross annual income (a total of all forms of income measured in Ethiopian Birr (ETB, the unit of currency in Ethiopia)				
Independent variables	Definition and measurement	Variable type	Hypothesized relationship	Identified relationships in the previous studies	
				Positive	Negative
AGE	Age of the HHH (in years)	Continuous	Positive		
AGESQ	Age of the HHH square(in years)	Continuous	Negative		
FAMSIAD	Family size in adult equivalent (in number)	Continuous	Indeterminate		(Sinyolo <i>et al.</i> , 2014; Tesfaye <i>et al.</i> , 2008)
FAMSIADSQ	Family size in adult equivalent square (in number)		Positive	(Sinyolo <i>et al.</i> , 2014; Tesfaye <i>et al.</i> , 2008)	
DEPRAT	Dependency ratio(in number)	Continuous	Negative		
TCULAND	Total cultivated land (hectar)	Continuous	Positive	(Ayele <i>et al.</i> , 2013; Legesse <i>et al.</i> , 2018)	
TLU	Total livestock holding of the HH in TLU)	Continuous	Negative	(Bacha <i>et al.</i> , 2011; Haji <i>et al.</i> , 2013)	
EDUC	Educational level of the HHH (in years)	Continuous	Positive	(Ayele <i>et al.</i> , 2013)	
PARTIRR	Participation in irrigation (irrigation user=0, otherwise=1)	Dummy	Positive	(Gebremariam & Ghosal, 2016; Ogunniyi <i>et al.</i> , 2018)	
DISMARK	Distance from farm plot to the district market(in walking hours)	Continuous	Negative		(Mengistie & Kidane, 2016)
SEX	Sex of the HHH (male=0, otherwise=1)	Dummy	Negative		(Mare & Girmay, 2016)
CREDIT	Credit service (0=Yes, otherwise=1)	Dummy	Positive		

EXTENSION	Extension service (Yes=0, otherwise=1)	Dummy	Positive
TRAINING	Participation on farming related training (yes=1, otherwise=0)	Dummy	Positive

2.3 Methods of data analysis

The quantitative data on socio-economic and demographic characteristics of the respondents were analyzed using descriptive analysis such as frequencies, mean, Chi-square analysis and t-test using SPSS version 24 software. The econometrics technique (Heckman two-step procedure) was employed to examine the determinants of farmers' participation on irrigation farming, and the effects on irrigation on HH income. The analysis of Heckman two-step procedure was determined using Stata version 14. The details on the specification of this model is presented as follow.

Econometrics model specification

Heckman two-step procedure was used to identify the determinants of farmers' participation in irrigation and to examine the effect of irrigation on HHs' income from other possible factors that affect income. Other researches applied Heckman sample selection model (Abdissa *et al.*, 2017; Asayehegn, 2012; Bacha *et al.*, 2011; Tesfaye *et al.*, 2008). The effect of the program may be under or overestimated if program participants are more or less able due to certain unobservable characteristics unless the selection bias is controlled. Therefore, in the first step using binary probit model the inverse mills ratio or the selectivity bias was determined based on maximum likelihood estimation (MLE). If the inverse mills ratio is significant it will be included as one explanatory variable in the second model that is the Ordinary least square (OLS) model to determine the effect of irrigation on the income of farm HHs. The Heckman two-step model estimation was done by using binary probit (MLE) in the first step and OLS was used in the second step.

$$D_i = \sum_{k=1}^k \gamma_k Z_{ik} + U_i \quad (1)$$

Let Z_{ik} be a group of k variables which represent the characteristics of a household i which influence the probability of participation in irrigation agriculture measured by a latent variable D_i and γ_k are the coefficients which reflect the effect of these variables on the probability of being an irrigation farmer.

$$Y_i = \sum_{n=1}^n \beta_n X_{in} + \varepsilon_i, \text{ observed only if } D_i > 0 \quad (2)$$

Let X_{in} is the group of variables which represent household i which determines the households' amount of income (Y_i) and β_n are the coefficients which reflect the

effect of these variables on households' amount of income.

\mathcal{U}_i and \mathcal{E}_i are the disturbances follow a bivariate normal distribution with a zero mean and variance σ_u and σ_ε respectively, and covariance $\sigma_{\varepsilon u}$.

\mathcal{D}_i is a dichotomous variable which takes the value of 1 = irrigator and 0 = otherwise. The estimator is based on the conditional expectation of the observed variable household income (\mathcal{Y}_i).

$$E(\mathcal{Y}_i/\mathcal{D}_i > 0) = \mathcal{X}\beta + \sigma_{\varepsilon u}\sigma_\varepsilon\lambda(-\gamma\mathcal{Z}) \quad (3)$$

λ is the inverse Mills ratio defined as $\lambda(-\gamma\mathcal{Z}) = \phi(-\gamma\mathcal{Z}/(1 - \varphi(-\gamma\mathcal{Z}))$; β and γ are the vectors of parameters which measure the effect of variables \mathcal{X} and \mathcal{Z} ϕ and φ are the functions of density and distribution of a normal respectively.

The expression of conditional expectation shows that \mathcal{Y}_i equals $\mathcal{X}\beta$ only when the errors \mathcal{U}_i and \mathcal{E}_i are not correlated, $\sigma_{\varepsilon u} = 0$; otherwise, the expectation of \mathcal{Y}_i is affected by the variable of equation 1. Thus, from equation 3:

$$\mathcal{Y}_i/\mathcal{D}_i > 0 = E(\mathcal{Y}_i/\mathcal{D}_i > 0) + \mathcal{V}_i = \mathcal{X}\beta + \sigma_{\varepsilon u}\sigma_\varepsilon\lambda(-\gamma\mathcal{Z}) + \mathcal{V}_i \quad (4)$$

\mathcal{V}_i is the distributed error term.

Qualitative data were collected using FGDs, KII and HH interviews. The composition of the interview participants include elderly farmers, young farmers, MHHs and FHHs. The views of the elderly farmers were important to verify the long-time irrigation practices of the community in the area. The qualitative data were coded in Nvivo software, organized and reduced into themes, interpreted and presented concurrently with the quantitative data in the presentation and discussion section.

2.4 Results and discussions

2.4.1 Socio-economic characteristics of respondents

The current study revealed that irrigation user HHs have higher gross income and farm income than non-irrigation users at $P < 0.01$ and $P < 0.05$ level of significance respectively as can be seen from the t-test statistics in Table 2.3. Irrigation user farmers found to have better income because SSI provides opportunity for farmers to produce market oriented vegetables, crops and fruits twice or thrice a year. Consequently, it enables farmers to get better farm income from the sale of such agricultural products. Using the farm income, the HH could invest into other income generating

activities like livestock rearing and they could also invest more on input on the rain-fed and irrigation plots to get better production. In the FGDs held with farmers, the participants noted that irrigation increases farmers' adaptive capacity to resist unexpected rainfall interruptions and associated harvest lose. Abebe (2017) reported similar finding in the study conducted at Arba Minch Zuria Woreda, Southern Ethiopia.

In this study irrigation user HHs have statistically significant higher HH size measured both in number and adult equivalent compared to non-users as presented in Table 2.3. This higher number of family size for irrigation users is related to the fact that irrigation is a labour intensive agricultural practice than rain-fed agriculture.

Table 2.3: Characteristics of respondents (continuous variables)

Variables	Irrigation	Mean	t-value	Sig.
Age	Irrigation User	41.40	1.27	0.204
	Non-users	39.73		
Family size in number	Irrigation User	5.94	4.61	0.000***
	Non-users	4.91		
Family size in adult equivalent	Irrigation User	5.94	4.61	0.008***
	Non-users	4.91		
Dependency ratio	Irrigation User	0.94	-0.67	0.504
	Non-users	1.00		
Education of HHH in years	Irrigation user	6.2	3.06	0.025**
	Non-user	5.5		
Total cultivated land in hectare	Irrigation User	0.89	8.43	0.016***
	Non-users	0.84		
Livestock holding in TLU^a	Irrigation User	3.94	4.98	0.000***
	Non-users	2.57		
Farm income in ETB	Irrigation User	35197.36	5.10	0.027***
	Non-users	15948.27		
Non-farm income	Irrigation User	10542.98	0.62	0.539
	Non-users	9552.96		
HH gross income	Irrigation User	44965.65	6.69	0.000***
	Non-users	24667.55		
Distance from farm plot to district market in walking hour	Irrigation User	2.733		
	Non-users	2.761	-0.316	0.752

***, **, and * significance P-values at 0.01, 0.05 and 0.1 respectively
^aTLU calculated based on Strook, Imana, Adnew, Browiecki, & Haweriat (1991)

In the FGD farmers reported that irrigators in most cases have hired labour force living regularly with the HH. In the case of total cultivated land holding, irrigation users and non-users have a mean of 0.89 and 0.84 hectares respectively with statistically significant difference at $P < 0.05$. Similarly, irrigators have statistically significant higher number of livestock holding in TLU with a mean of 3.94 than non-irrigators with mean of 2.57 (Table 2.3). In the study districts where the occurrence of recurrent drought and erratic precipitation are common, farmers consider livestock rearing as an alternative economic activity to sustain their livelihood. This is due to the situation that livestock sector is relatively more resistant to unexpected climate variability compared to crop production. Moreover, in the view of FGD participants the number of livestock holding is an indicator of wealth status in their community. This implies that SSI can create the potential for the users to have more number of livestock as they have better income.

The Chi-square analysis indicated that the sex of the HHH affects HHs' participation in SSI at $P < 0.05$ statistically significant level as shown in Table 2.4 in which FHHH found to be less participant in irrigation. This could happen due to two reasons, one factor is the dominance of males being HHHs due to the patriarchal culture of Ethiopia. The second factor is related to some FHHHs preference to lease their irrigable land for other farmers due to the labor-intensive nature of irrigation and some inconvenient irrigation practices for women like night time watering and due to water based conflicts.

In relation to HHs' practice in using credit service, about 71% and 77% of irrigators and non-irrigators have never used credit service respectively. Farmers who participated in the FGD reported the limited provision of credit service in their locality. Moreover, the FGD participants noted that though the farmers working in irrigation agriculture want to take credit to purchase different agricultural inputs, they don't take credit due to the fear of the interest rate. This implies the need to provide appropriate credit services for farm HHs with low or if possible no interest rate through government subsidy to increase farmers' investment in productivity-enhancing technologies like SSI to averse the negative effects of drought on farm HHs livelihood.

Farm HHs' perception of the land being fertile increases their participation in irrigation at $P < 0.01$ level of significance (Table 2.4). This implies that land fertility-enhancing techniques should be

promoted in irrigated plots as a package with SSI so as to enhance farmers' investment in SSI to overcome their life challenges associated with drought and erratic rainfall situation in the study districts. The land in irrigating plots commonly cultivated twice a year and in some situations thrice a year. Such cropping practices degrade the natural fertility of the land and productivity declines in the long run. In such a situation, some farmers quit working on irrigation sustainably. This has great implications on the need to work on land reclamation and land fertility-enhancing mechanisms so as to enable smallholder farmers to sustainably work on irrigation to overcome the adverse effects of climate variability induced livelihood challenges. Furthermore, participation in farming-related pieces of training increase farmers' participation in irrigation agriculture. Thus, farming-related training should be taken as an integral component in the adoption of agricultural technologies including irrigation.

2.4.2 Determinants of farmers' decision to participate in irrigation farming

Probit regression model results (Heckman First-stage model results)

In the first step of Heckman two-stage model, Probit regression model was estimated to analyze the determinants of farmers' participation in SSI farming as can be seen in Table 2.5. The overall model is statistically significant ($P < 0.01$). Therefore, the selected observable characteristics explain the probability of irrigation use appropriately. The pseudo-R-square shows that about 72.15% of the variation in the participation model can be explained by the included explanatory variables. A positive sign of the coefficients shows an increase in the probability of farmers' participation in SSI farming while a negative sign shows a decline. The findings of previous empirical investigations in different parts of the world revealed the role of multiple complex factors that affect household participation in irrigation (for example Ogunniyi *et al.*, 2018; Legesse *et al.*, 2018; Sinyolo *et al.*, 2014; Sithole *et al.*, 2014). The finding of this study also revealed that different factors determine HHs' decision to participate in SSI in the study kebeles (Table 2.5), which are discussed in the forthcoming paragraphs.

Age of the household head

The current study indicated that as the age of the HHH increases, the probability of the heads' decision to participate in SSI farming increases significantly at $P < 0.05$. However, this relationship between age and participation in irrigation is not linear. As can be seen from the negative coefficient of age square in Table 2.5, the HHHs' decision to participate in SSI begins to decline significantly ($P < 0.01$) after a certain age level. This might be related to the labor-intensive nature of irrigation agriculture. As the head gets older, he/she might be physically weak to spend most of his/her time working in the irrigating plot preparing farmland, plowing, applying seed, fertilizer, insecticide, watering, weeding, and harvesting. This finding is in line with some previous empirical studies by Sinyolo *et al.* (2014) and Bacha *et al.* (2011). This has implications on the labor-intensive nature of irrigation in the area, which is not convenient for elderly people. Thus, the introduction of low-cost agricultural technologies can be a viable solution to reduce the intensive

Table 2.4 Characteristics of respondents (categorical variables)

Variable Definition		Irrigation user		Irrigation non-user		Total		Chi-square value	Sig.
		Freq.	%	Freq.	%	Freq.	%		
Sex	Male	198	77	124	72	355	82	5.01	0.025**
	Female	61	23	48	28	76	18		
	Total	259	100	172	100	431	100		
Credit service	Yes	75	29	39	23	114	26	0.14	0.148
	No	184	71	133	77	317	74		
	Total	259	100	172	100	431	100		
Extension service	Yes	205	79	140	81	345	80	0.33	0.568
	No	54	21	32	19	86	20		
	Total	259	100	172	100	431	100		
Perception on land fertility	Fertile	152	59	34	20	186	43	63.82	0.000***
	Infertile	107	41	138	80	245	57		
	Total	259	100	172	100	431	100		
Participation in training	Yes	140	54	52	30	192	45	23.74	0.000***
	No	119	46	120	70	239	55		
	Total	259	100	172	100	431	100		

***, ** and * significance at P-values 0.01, 0.05 and 0.1 respectively

labor demand for irrigation. Consequently, the introduction of such supportive agricultural low-cost irrigation technologies can be a good source of income to compensate for HH asset degradation that can occur during old age due to many factors.

Access to extension service

Contrary to our prior hypothesis, farmers' participation in irrigation is not affected by extension service although many findings indicate the positive and significant relationship among the two variables, for instance, Yihdego *et al.* (2015). Based on the data obtained from FGD participants, there is a limited frequency of contact between extension workers and farmers in the study Kebeles. In Arata Chufa and Dodicha SSIS, farmers noted that although there are extension workers in their area, they haven't got technical support from them practically. This weak extension worker-farmers contact affects the performance of SSI, which consequently affects the participation of farmers in irrigation as farmers can lack technical support from extension workers.

The educational level of the household head

This study revealed that education of the head affects participation in SSI farming positively and significantly ($P < 0.05$). Attending formal education helps farmers to get more knowledge about the operational aspects of the irrigation technology, and to adopt better irrigation technology. Other previous findings also confirm the current result (Legesse *et al.* 2018; Ogunniyi *et al.*, 2018). This implies that creating better educational access for the farm HHs in rural Ethiopia significantly increases farmers' agricultural technology adoption, which can consequently lead towards improving agricultural productivity and can contribute to the goal of improving food security.

Family size in the adult equivalent

As the family size in adult equivalent increases, farmers' decision to participate in irrigation increases significantly ($P < 0.05$). Yet, the relationship is not linear as it can be seen from the negative coefficient of family size in an adult equivalent square ($P < 0.01$) in Table 2.5. Although the probability of farmers' participation in irrigation increases as family size in adult equivalent increases, this likelihood declines after a certain number of family size. This might happen as the family size become larger, it could restrict HHs' investment in SSI as they might have lots of other expenses for HH members. Also, family members might be engaged in other livelihood options like non-farm activities; Ogunniyi *et al.* (2018) and Yihdego *et al.* (2015) have similar result.

Table 2.5: Determinants of farmers' participation in SSI: Probit regression model

	Coefficients	Std.Err.	P> z
Age	.566	.024	.047**
Age square	-.081	.001	0.009***
Sex	.603	.290	0.048**
Family size in adult equivalent	.052	.020	0.015**
Family size adult equivalent square	-.654	.237	0.006***
Dependency ratio	-.038	.172	0.825
Extension service	.476	.325	0.144
Credit service	.351	.268	0.190
Cultivated land size	-.446	.142	0.002***
Number of livestock in TLU	-.458	.046	0.041**
Distance from farm plot to district Market	-.315	.140	0.024**
Educational status	.347	.174	0.046**
Access to irrigation land	3.354	.304	0.000***
Perception on land fertility	.791	.259	0.002***
Participation in farming related training	.274	.234	0.242
_Cons	-2.385	1.521	0.117
Log likelihood = -75.994507			
Number of obs = 411			
LR Chi2(15) =393.70			
Prob > Chi2 = 0.0000			
PseudoR2 = 0.7215			
***, ** and * significance at P-values 0.01, 0.05 and 0.1 respectively			

Sex of the household head

The study indicated that FHHs are less likely to participate in SSI farming compared to MHHs ($P < 0.05$). The FGD participants at Gulba Aluto SSIS reported that FHHs must use farm laborers if they want to produce in their irrigable land on their own. The participants further noted that in most cases FHHs simply rent out their land for other farmers or engage in sharecropping as they have financial limitations to use hired labor. In the study districts, the existing SSI practices are not convenient for FHHs due to high competition for irrigation water and associated conflicts for watering vegetables particularly when irrigation water is scarce. Furthermore, interviewed farmers at Bochessa irrigation site mentioned lack of time as the main factor that results in women's low participation in irrigation as they have multiple responsibilities such as household chores, caring for children, and other daily life routines. Abebe (2017) also pointed out that night time irrigation water distribution schedules and the high labor demand irrigation farming constraints female

farmers' participation in SSI. Besides, there is a gap in the motivation to invest in irrigation among FHHs and MHHs. Haileselassie *et al.* (2016) also revealed that FHHs are less motivated to participate in labor and capital intensive irrigation farming as they have limitations in finance, inputs, labor, and market information.

Besides, FHHs having male child/children can be successful in working in irrigation. FHH FGD participant at Arata Chufa SSIS gave an account for this "if I had no son, I would suffer a lot to work in SSI. However, after I got divorced from my husband, thanks to my sons I am working equally like any other MHHs in irrigation farming." Generally, the FGD participants agreed that FHHs with and without sons are not participating equally in irrigation. If the FHH has no son, her status is minimum in the society. This is related to the gender perspectives in Ethiopia, which is dominantly male-headed patriarchal context. This implies that irrigation technologies need to be gender-sensitive in particular it should be female-friendly both in terms of the technical and institutional context to provide equitable benefit for MHHs and FHHs.

Perception of land fertility

The current study showed that HHH who perceives his/her farmland is fertile has more likelihood to participate in SSI farming than those farmers who perceive their land being infertile ($P < 0.01$). This indicates that farmers' perceptions about their land being fertile might encourage farmers to decide to work on irrigation expecting better returns from investing in it. Otherwise, they couldn't have the motivation to invest in irrigation agriculture and they might opt for other livelihood systems like to rent out their irrigable land and they might engage in livestock sector or non-farm activities. Similar findings were reported by (Abdissa *et al.*, 2017; Bacha *et al.*, 2011; Sinyolo *et al.*, 2014).

Number of livestock holding

It has a significant and negative relationship with farmers' participation in SSI agriculture ($p < 0.05$). Both ADJK and Zeway Dugda districts are characterized by the recurrent occurrence of drought. There was a severe drought in both districts during the cropping season when the data for this study was collected. In the FGD held with farmers, they explained that livestock rearing is insurance during unreliable rainfall situations instead of both rain-fed and irrigation farming.

Irrigation user farmers pointed out that pests and diseases severely affect their irrigation farms during drought conditions as a high temperature creates a conducive situation for the proliferation of crop pests. This suggests that the need to give policy attention to create a conducive environment to strengthen the role of the livestock sector for both irrigation users and non-user farmers to enhance their adaptive capacity to the changing climate in the drought-prone parts of Ethiopia. Abdissa *et al.* (2017) reported a similar relationship between livestock holding and participation in SSI.

Size of cultivated landholding

Farmers who own a large amount of total cultivated landholding are less likely to participate in irrigation ($P < 0.01$) as can be seen in Table 2.5. Haji *et al.* (2013) found the same result in their study at Eastern Hararghe. The FGD participants explained that they prefer not to work in irrigation farming due to the risks of irrigation with the outbreak of vegetable pests and diseases associated with unpredictable rainfall situation in the area, which adversely affects the productivity of SSI. Hence, farmers prefer rain-fed farming unless there is a need for intensive cultivation twice or thrice within a year if the farmer has a small plot of land. However, (Abdissa *et al.*, 2017; Yihdego *et al.*, 2015) found a positive and significant relationship between cultivated landholding size and participation in irrigation. So, future investigations are important to analyze the relationship between cultivated landholding size and farmers' decision to participate in irrigation considering different agro-ecological and climatic zones.

Distance from farm plot to district market

This variable affects farmers' decision to participate in irrigation negatively and significantly ($p < 0.05$). Farmers whose farm plots are located in a distant area from the district market are less likely to participate in irrigation than farmers whose plots are located in the proximity to the market. Market accessibility determines farmers' access for agricultural inputs and they can get better profit from vegetables grown in irrigation fields. Yihdego *et al.* (2015) also reported a similar finding. Therefore, to enhance farmers' participation in SSI, market linkages and access should be facilitated for smallholder farmers whose livelihood systems are under the threats of climate variability. The FGD participants in Shelad SSIS further elaborated the problem of limited market access due to a lack of road construction. Consequently, during rainy season farmers use

their irrigable land for maize production that can be used for household consumption instead of producing vegetables, which can be possible to produce 50 or 70 quintals for the market due to the constraint of road. According to the view of farmers, if there were no road problems, the production of Shelad SSIS can be enough for many areas let alone the district.

Our big challenge in Shelad is the road. We get sick³ due to our irrigation vegetables whenever it rains. If we get a road connection, we can take our vegetables into the market, we can get high profit and we can get economically empowered. So that we can buy motors, and we can invest more in irrigation because our Kebele is surrounded by water bodies (Irrigators FGD, Shelad site).

The finding showed that not only distance that affects farmers' decision to participate in irrigation rather the type of road which connects the irrigation scheme with vegetable markets. Generally, poor market access for irrigated vegetables found to be the major challenge for irrigation user farmers in all investigated SSIS and it discourages farmers' decision to participate in irrigation due to expected economic losses. This has implications on the sustainability of irrigation farming in the study areas. Thus, the government and other development actors should consider road accessibility among the priority intervention areas to improve the performance of SSIS.

Access to irrigation land

As we hypothesized, farmers' who have access to irrigation land positively and significantly ($P < 0.01$) determine their decision to participate in SSI in the study districts. Based on the discussion with farmers in the FGDs, a HH is considered as lucky and advantageous if his/her landholding is found in the irrigation command area. On the other hand, FGD discussants indicated that the poor farmers rent out their irrigable landholding for wealthy farmers as they are unable to cover the high input costs that irrigation farming demands. This reveals the situation in which having access to irrigation land is not a guarantee for farmers to participate in irrigation farming unless agricultural inputs are provided for farmers with affordable prices and assisted with an extension program. This research finding is supported by the findings of (Yihdego *et al.*, 2015).

³ It doesn't refer to physical sickness rather feeling of worry due to lose as a result of not selling their irrigated vegetables due to lack of access to market because of transportation problem.

2.4.3 Effect of small scale irrigation on household income:

Heckman second-stage outcome model results

The result of Heckman second-stage outcome model revealed that different factors affect the amount of farm HHHs' income in the study districts as presented in Table 2.6. The variables sex of the HHH, family size in adult equivalent, family size in adult equivalent square, dependency ratio, cultivated land holding size, distance from farm plot to district market, HHH's educational level, participation in irrigation and lambda (inverse mills ratio) were found statistically significant affecting the amount of HHHs' income. Lambda (inverse mills ratio) was found significant ($P < 0.01$). This shows the presence of selectivity bias and this has indication on the appropriateness of using the model. Similar findings were reported by (Abdissa *et al.*, 2017; Yihdego *et al.*, 2015). The positive coefficient of lambda indicates that the disturbance terms in the participation and outcome equations are positively correlated. The significant result indicates the presence of unobserved determinants of HHHs' participation in SSI than those variables included in the model. These factors most likely have positive relationship with HH participation in SSI. The next paragraphs presents discussion on some of the most important determinants of HH income.

Participation in SSI: Controlling other variables, HHHs' participation in SSI has positive and significant effect on their income ($P < 0.05$) as shown in Table 2.6. Thus, irrigation user HHHs have significantly better annual income than non-irrigation users. This finding is in line with our prior hypothesis and some previous research results (Gebremariam & Ghosal, 2016; Hagos *et al.*, 2012; Hirko *et al.*, 2018). This is due to the enabling factors that irrigation provides for the users to cultivate twice or thrice a year than non-users who cultivate once in a year even under the severe risks of crop failure due to frequent occurrence of drought in both districts. Besides, irrigators produce cash crops, which contributes for better HH income than non-irrigators. Astatike (2016) also noted that cash crop oriented production of irrigators is a contributing factor for enhanced HH income of irrigators in northern part of Ethiopia.

The farmers in the FGDs pointed out that irrigation serves as a relatively better livelihood strategy in their area especially during erratic rainfall condition as it reduces or avoids rainfall variability induced crop failures. However, irrigation user farmers underlined the problem that SSI faced challenges to be a sustainable agricultural system to support their livelihood through providing

food and better income during severe drought situation like the 2015/2016 in which they lost their crop in the rainfed and the vegetables in the irrigation farms. The main challenge that hinders the sustainability of irrigation farming during drought occurrence is scarcity of irrigation water as the volume of water reduces or the rivers even dry in such situation. Consequently, irrigators have been under government food aid support like non-irrigation users in both study districts. The FGDs held with irrigators at Dodicha *Kebele* indicated the situation in their words “if there were no government support in food aid last year, you may not find us alive here” (Irrigators FGD, Dodicha *Kebele*). Furthermore, the FGD participants elaborated that small irrigable landholding is the other challenge that hinders the sustainability of SSI in supporting agricultural productivity, food and HH income when there is severe drought and no production in rainfed fields.

Awulachew (2019) who reported that even the monthly changes in weather condition constitute significant effects on agricultural production let alone seasonal changes in weather condition. This implies that to enhance the adaptive capacity of smallholder irrigators under severe drought situation drought resistant crops should be planted and provision of sustainable sources of irrigation water has to be designed with proper climate variability and drought occurrence forecasting. Furthermore, well performing extension packages are also important so as to give the necessary training and advisory services for irrigators to enhance their benefit from irrigation.

Table 2.6: Factors affecting HH income: Heckman second-stage outcome model results

	Coefficients	Sta.Err.	P> z
Age	1387.876	1387.024	0.317
Age square	-19.163	15.876	0.227
Sex	-9275.06	5504	0.047**
Family size in adult equivalent	-1199	5328.207	0.024**
Family size adult equivalent square	784.565	474.565	0.098*
Dependency ratio	-954.716	2697.327	0.072*
Extension service	9164.423	5892.759	0.120
Credit service	7172.815	5593.258	0.200
Cultivated land size	1845.18	4467.645	0.010**
Number of livestock	94.575	975.703	0.923
Distance from farm plot to district Market	-68.429	35.899	0.057*
Educational status	540.297	3900.261	0.037**
Participation in irrigation	1830.18	22266.93	0.028**
Participation in farming related training	2378.028	4527.017	0.599
Lambda	5955.23	10889.1	0.000***
_Cons	14896.11	38279.84	0.698
Number of Obs = 411			
Censored Obs = 255			
Uncensored Obs = 156			
Wald Chi2 (15) = 77.93			
Prob > Chi2 = 0.0000			
***, ** and * significance at P-values 0.01, 0.05 and 0.1 respectively			

Amare & Simane (2017) identified SSI as one of the adaptation mechanism to climate change. However, the authors further recommended that farmers should diversify their livelihood from being dependent on farming activities to off-farm and/or non-farming income generating activities. Mengistie & Kidane (2016) also indicated the problem of irrigation water shortage due to continuous drought and dry spells causing the volume of rivers to decline among the irrigators in North Wollo, Ethiopia. Furthermore, future researches are necessary on how to design SSI to be a sustainable source of agricultural production, income and livelihood strategy in the drought prone arid and semi-arid areas like the study districts. Generally, farmers' participation in irrigation increases the amount of gross HH income, however, such positive effect of irrigation on HH gross income cannot be sustainable unless there is sustainable provision of irrigation water sources during the time of chronic drought.

Sex of the HHH: In this study, MHHs found to have better income compared to FHHs. The main reason for this difference in income among the two sex groups is the situation in which most of the time FHHs engage in share cropping and sometimes lease out their irrigable landholding. Hence, the economic benefit of irrigation farming is minimal for FHHs. This has policy implication on the need to make SSI technologies to be gender sensitive. Thus, future policies and SSI practices needs to be framed to create equitable benefit among FHHs and MHHs in Ethiopia. Addressing gender-based equitable use of water, land, and agricultural technologies including SSI can lead Ethiopia into sustainable rural development. Gender inequality in access to productive resources such as land, water, credit, and technology are closely related to women's poverty and economic and social exclusion in the study conducted at Gamo Gofa Zone, Ethiopia (Mare & Girmay, 2016). Awulachew (2019) suggested that rural women can get more benefit from irrigation agriculture if they get access to land and water rights and actively participate in WUAs.

HH size in adult equivalent: This variable influences HH income negatively and significantly ($P < 0.05$) as can be seen in Table 2.6. However, the relationship between family size in adult equivalent and HH income is not linear. The positive and significant ($P < 0.1$) coefficient of family size in adult equivalent square shows that after a certain point with increasing of family size the HH income also increases. Bacha *et al.* (2011) found similar result and termed U-shaped relationship. One of the reasons for this might be as the family size increases, family members might engage in different income generating activities and can contribute to increase the HHHs' income. The other contributing factor might be government's food aid provision for the farmers as relief for the chronic drought during the cropping season at the time of this data collection. As the size of the HH member increases, the amount of wheat distributed for the HH increases. Most of the farmers sell the wheat in order to get money to purchase other consumable items and this might likely affect the data on income generated due to the effect of other variables. Therefore, future investigation of the impacts of agricultural technologies like irrigation on HH income or other livelihood components should emphasis interventions like food aid provision in their research.

Size of cultivated landholding: In line with our prior expectation, as the size of cultivated land holding increases, HHs' income increase significantly ($P < 0.05$) keeping other variables constant as can be seen from Table 2.6. The higher the cultivated landholding, farm income can be higher and it in return contributes to higher HH gross income. Land is the basic input in agriculture. Thus, HHs having more land have better opportunity to produce more and generate better income. This finding is in line with theory and some previous studies (Astatike, 2016; Yihdego *et al.*, 2015). However, the discussants in the FGDs complained about the small landholding size, which constrained their benefit from SSI in both study districts. Hence, as there is limited alternative to reallocate land to increase HHs' landholding, it is better to design alternative and feasible strategies to increase the productivity of the existing farm lands through the adoption of soil and water conservation mechanisms by the farmers with the support of agricultural development agents.

Number of livestock holding: In this study the number of livestock holding doesn't affect the income of HH, which is contrary to our hypothesis and to some previous findings like (Belay & Beyene, 2013; Yihdego *et al.*, 2015). The FGD participants verified that the livestock sector was also adversely affected by the chronic drought due to lack of forage and water, which causes even the death of some livestock during the cropping season of this data collection. In addition, farmers were discouraged to sell their livestock due to low market price as livestock fattening was hindered due to drought induced vulnerabilities. Thus, although livestock is more resilient than crop production to climate variability, under severe drought situation the livestock sector can be under risky situation. Thus, agricultural development workers and climatologists have to work in collaboration to give the right early warning on expected climate variability induced risks on livestock sector. In such a way farmers can be supported not to lose their livestock either by destocking their livestock before it is damaged or to make ready fodder during good cropping seasons. This implies that appropriate management of the livestock sector is critically important to enhance the contribution of the sector for enhancing HHs' income especially during the time of drought in which the crop production sector is highly vulnerable to the damaging effects of drought.

Educational level of the HHH: In the current study educational level of the head positively and significantly influences the HHs' income (Table 2.6). As the formal years of schooling of the head

increases, the head can have wider understanding on how to work to attain the objective of maximizing HHs' income using different livelihood strategies. Moreover, as the educational level of the HHH increases, the head might have multiple opportunities to participate in income generating activities. Such situations can produce positive and significant relationship between income and HHH's level of education. The findings of Ayele *et al.* (2013) confirms our result. However, some previous findings like Belay & Beyene (2013) indicated that educational level of the HHH has no effect on the HH income in Deder district, Ethiopia. Such variation in relation to the effect of heads' level of education on HH income might be affected due to existing situations related to farmers' access to education and other accompanying farming related trainings. Thus, interventions have to be done to increase farmers' access for educational services in rural areas in order to improve the level of farmers' education. Farmers' having better educational level can become more knowledgeable about different productivity enhancing techniques such as various irrigation practices, water and soil conservation, livelihood diversification and the like. This implies that the more the farmers are educated, they can get more income and other benefits from irrigation. Consequently, they can practice different livelihood strategies that can ensure sustainable rural livelihood development.

Distance from farm plot to district market: The relationship between HH income and distance from farm plot to district market is negative and significant in line with our prior expectation. In all the FGDs farmers strongly mentioned market constraint as a big challenge in accessing agricultural inputs and selling their production from irrigated fields. Sometimes, farmers even left their perishable vegetables like tomato, cabbage and onion in the farm plot for livestock to graze it when the price is too low and having limited transportation and market access. Furthermore, the far walking distance from farm plot into district market reduces farmers' income gain from their irrigation due to the intervention of brokers in fixing irrigated products prices. The FGD discussants of Shelde SSI users view can be taken as a good account for this case.

The income we get depends on market situation, which is governed by brokers. We have no link with merchants of our product rather brokers play the role in deciding the price of our production. We are equally sharing our income obtained from irrigation with brokers. No one is controlling the brokers, they decide price of productions as they want. We farmers have no means to change the price once decided by the brokers. For example in 2015 production year, I produced 48 quintals of onion and sold 8000 Birr. I have lost;

there is no profit. Let alone profit, I was unable to cover my input expenses (Irrigators' FGD, Shelad site).

This implies that access to market and market linkage are crucial factors that determine the amount of income that can be obtained from SSI. This has big implication on the role of market and transportation linkage on the contribution of SSI on household income and sustainable rural livelihood development. Hence, the Ethiopian government has to prioritize and work strongly on creating good market access and transportation services for farmers in ATJK and Zeway Dugda districts to enhance the benefits from SSI in terms of generating better HH income and enhancing sustainable rural livelihood development. Mengistie & Kidane (2016) have similar finding as they pointed out transportation, far distance from market, low bargaining power and low prices of irrigated products as the major challenges that hindered the economic benefit of SSI in North Wollo, Ethiopia.

2.4.4 Types of farmers' participation in irrigation scheme management

According to Alam *et al.* (2012), participation is a process in which stakeholder's influence and share control of development initiatives, decisions, and resources that affect them. The current study also showed that once a farmer becomes a member of WUAs, the farmer has the responsibility to participate in different forms in irrigation scheme management to enhance the sustainability of the schemes. Based on the data collected using household interview, the participation of farmers in irrigation scheme management has different forms as it is presented in Table 2.7. Participation here refers to farmers' practices that they most of the time related to the management of the scheme. The finding is further elaborated using the data collected from farmers' FGDs and KII with people working in irrigation institutions at the local level.

Irrigation scheme infrastructure maintenance and operation

According to Sharaunga & Mudhara (2018), maintenance of irrigation infrastructure comprises periodic maintenance which implies dredging the canal bed, reinforcing the canal banks, and repairing the fence; it has also regular maintenance including cleaning the canal bed of aquatic weeds. The current study revealed that majority of the HH interviewee (37/47) participate in irrigation infrastructure maintenance and operation activities. In all investigated irrigation schemes farmers have a regular schedule on canal bed cleaning; the days are fixed by the meeting in the presence of all WUAs members by the block committee leader. There is a local WUAs committee

that follows up the participation of irrigation users in canal cleaning using farmers' labor; the committee has its own code of conduct. The violation of this local code of conduct results in penalties on the farmers to pay a certain amount of money, which varies from one locality to the other locality. Carter & Danert (2006) indicated that irrigation infrastructures built from local materials regularly damaged, but can often be repaired by communities themselves. For instance, the participants of FGDs in Shelad SSIS (gravity type of irrigation) verify this finding.

We have the schedule of cleaning the canal bed once in every 15 days. The team leaders of the small groups check the availability of members for cleaning the canal. If a person is absent one day in canal cleaning, he/she will be penalized 40 ETB (Irrigators FGD, Shelad site).

Table. 2.7: Types of farmers' participation in irrigation scheme management

Type of participation	Number of HH interviews (Total=47)
Irrigation scheme infrastructure maintenance and operation	37
Financial contribution	33
Attending meeting	21
Labour contribution among water users	32
Conflict resolution	14
Ratification of code of conducts for WUAs	25
Planning	7
Implementation	19
Monitoring	8
Evaluation	10

On the other hand, the study showed that farmers lack the skill to participate in irrigation infrastructure maintenance in the case of pressurized irrigation schemes at Dodich, Bochessa, and Gulba Aluto SSIS. The KII with the chairman of Dodicha SSIS indicated that poor quality of motors incurs financial burden on the farmers as the committee purchase poor quality motors from the merchants due to lack of know-how about the quality of the motors. Therefore, farmers contribute money for the maintenance of the motor based on the cost requested by the technician if the motor becomes out of function suddenly. For instance, if the technician asked 10,000 ETB,

it will be divided by the number of the WUAs members and every member contributes the assigned money. The committee of the WUA members deposited money collected from every member whenever the users obtain vegetable production in order to purchase a new motor or if case their motor suddenly becomes out of function. The KII strongly underlined the need for government intervention in the provision of high-quality motors for irrigators in their locality.

There are illegal low-quality motors that come to the market without the permission of the government. We simply buy from merchants without the approval of the government stamp for its quality. Such motors stop working after it works only for one month. The government has to follow up and give quality assurance for the motors. For example, we pay 30,000Birr to buy a motor believing that the motors are of high quality. We farmers have no awareness about the quality of the motors. We buy high copy (forged) motors the same price with original motors (KII, WUAs chairperson, Dodicha site).

Furthermore, the KII highlighted the technical limitation they have in motor maintenance and the need for training to minimize the expenses of the WUAs. Carter & Danert (2006) emphasized that the poor quality of engineering aspects of SSI intervention might attribute due to inadequate data, limited experience, or dogmatic attitudes to farmers by professional staff. This implies the crucial role of the government in providing technical support for smallholder irrigators. Hence, it is recommended that WUAs should be trained to have skills in maintaining motors and other irrigation infrastructure by the government and other stakeholders. According to Carter & Danert (2006), durable engineering structures are not always the best for SSI in terms of community maintenance without long term external assistance, thus, irrigation engineers have to listen and learn from farmers' indigenous knowledge to enhance the adoption of the skills by farmers.

Farmers' labor contribution in irrigation management

The present study indicated that among the interviewed farmers (32/40) participate in labor contributions in the irrigation scheme management (as shown in Table 2.7). For example, the entrance of livestock into the irrigated command area is prohibited. Therefore, every WUA member has assigned schedules to prevent the entrance of livestock in the field turn by turn especially during market days in which most farmers don't stay in the farm field. For instance, in Shelad SSIS three individuals are assigned for one day on Monday and Friday, which are market

days in the area. In market days thefts might also enter into the farm plots to steal vegetables, hence, the assigned farmers have the responsibility to ensure the security of the irrigated farm. Besides, irrigation sometimes demands collective labor contribution to prepare the land, plow land, collect vegetables, and others. However, the labor contribution of farmers might not be long-lasting unless they are economically benefited from SSI. Carter & Danert (2006) noted that farmers' participation irrigation scheme management is determined highly by economic factors. Thus, without significant short-term production and/or income gains, farmers may not consider their participation in SSI to be worthwhile. Without long-term benefits, sustainability will be compromised (Carter & Danert, 2006). This implies that local governments should ensure enhancing the economic benefits of farmers in order to increase their free labor contribution.

The financial contribution of irrigation users

The finding of this study showed that irrigation user farmers participate in contributing money for various purposes. The major contributions include irrigation infrastructure maintenance and operation, purchasing motor, and paying penalties due to violation of some WUAs codes of conduct. Farmers can be penalized to pay money if they don't participate in canal cleaning based on the schedule, don't plow his/her irrigated land, if his/her livestock entered in the irrigated command area, violet irrigation water schedule, and others. For instance, the code of conduct in Shelad SSIS states that if a farmer doesn't plow his land in a certain cropping season, he/she will be penalized 250 ETB in the first round. If he continues not to plow for the second round, he will be penalized another 250 ETB. However, if the farmer fails to plow for the third round, the issue will be taken into the WUAs committee decision; the committee has the mandate in which if the father is unable to plow his land, the WUAs transfer the land from the father to his son based on the code of conduct given by the government stating that land is under the government ownership and water is public property.

The KII conducted with WUAs chairman at Bochessa irrigation site elaborated on the rationale behind forcing the farmers to plow and produce on their irrigable plot even by penalizing those who don't produce on their land. Accordingly, the KII noted that if the farmer doesn't plow his/her land, the household will slide into poverty, conflict might occur within the household, and the farmer might engage in theft (referring social crisis) as far as he is not producing. Furthermore, if

a farmer is not producing in his/her irrigable land, it has an adverse effect on the neighboring farmers as pests reproduce on the bare land, and livestock might also enter to graze the land. Thus, the code of conduct considers multiple implications in forcing farmers to produce on their irrigable land under the strict role of the code.

On the other hand, although farmers made different financial contributions while they are members of WUAs, they have lots of complain about the lack of transparency on the expenses which are done by the committee members of the WUAs. The interview conducted with a 48 aged male farmer at Dodicha SSIS can be a good account for this. Fuel

Our WUAs committee bought two benzene driven motors. Once we plant vegetables, the motor stops working. The committee took the motor in the district town for maintenance. Once it is maintained, they (committee) came to us and said 'we paid this much money for motor maintenance.' We farmers simply accept what the committee says and there is no solution even if we go to district level as the committee have links with some corrupt officials at the district. Thus, farmers are still in poverty though they have irrigable land (HH interview, 48 years old, male farmer, Dodicha site).

This implies that little attention is given to consider the insights and inputs of the community in forming irrigation institutions at the lowest level, which consequently affects the acceptability and effectiveness of WUAs committee. IFAD (2005) indicated the lack of community participation in the actual investment and implementation in SSI projects. Kujinga (2002) also noted the high costs of operation and maintenance of irrigation schemes in a centralized system, the poor financial viability of schemes and deteriorating infrastructure have led to the need for effective models to manage irrigation schemes. Thus, the local government and other actors have to assess the needs, feelings and interest of local community with regard to the management and performance of WUAs.

Attending WUAs meetings

The result of this investigation revealed that members of WUAs attend different meetings. Some of the meetings have fixed schedule while others can be called by WUAs committee whenever there is a need to conduct meetings for urgent cases. In Shelad SSIS, all the 277 WUAs members

meet once within 2 months. The chairman of the local level WUAs committee read the code of conduct for the whole members, and then it can be approved or cancelled by the agreement of the WUAs. In the views of HH interview participants, attending WUAs meeting doesn't entail active participation as the members perceive decision making is the sole role of WUAs committee as can be seen from the responses in Table 2.7. This implies that poor understanding about the role of community participation by different stakeholders result in poor performance of WUAs in maximizing community participation in irrigation management. Yami (2013) have similar finding stating that ensuring community participation has been a challenge to irrigators in Ethiopia. Generally active community participation is key for the sustainability of SSIS, which is a communal property whereby the act of one individual can have significant positive or negative impact upon all the other users.

2.4.5 Effect of irrigation on HH income and its Implication on livelihood sustainability

The study proofed that irrigation user farm HHs characterized with significantly higher gross income than non-irrigation users in the drought prone CRV of Ethiopia. Yet, the contribution of SSI towards generating HH income has been facing challenges to ensure sustainable rural livelihood. According to Chambers (1987) the livelihoods and survival of human individuals, households, groups and communities are vulnerable to stresses and shocks. Stresses are normally continuous and cumulative, predictable and distressing, such as seasonal shortages, rising population or declining resources. Shocks are impacts which are typically sudden, unpredictable, and traumatic, such as fires, floods (Chambers, 1987). Hence, any definition of livelihood sustainability has to include the ability to avoid, or more usually to withstand and recover from such stress and shocks. The study districts are characterized with the occurrence of chronic drought and erratic rainfall pattern. Consequently, crop failure, food shortage, lack of adequate HH income and other challenges become the serious livelihood threats of both irrigators and non-irrigators. In such circumstances, both irrigation users and non-users have received food aid from the government. This implies that in ATJK and Zeway Dugda districts SSI has limited capacity to enhance sustainable rural livelihood development because SSI failed to support smallholder farmers' livelihood system to avoid shocks and recover from drought and other climate variability induced livelihood stressors. Hansen, Dilley, Goddard, Conrad & Erickson (2004) emphasized that

climate variability has impact on HH's access to food by affecting agricultural production, income, local food prices and in some cases the economy of an entire region.

Furthermore, the study indicated that the income of FHHs is less than that of MHHs, which showed the existing discrepancy on the effects of SSI on HH income in terms of gender. According to Parker *et al.* (2016) and Zwarteveen (2008), the ongoing practices at the global level are indicators of gender gaps in the participation at irrigation farming and taking decision making power at the local level irrigation governance institutions in which male dominance in leadership are common. Equity is the key concept in the perspective of sustainable development. Thus, the gap in the income gain from SSI based on gender undermines its role for running sustainable rural livelihood development. IFAD (2007) and Yami (2013) also emphasized that most women farmers are marginalized, poor, and vulnerable to food insecurity although the role of women in agriculture particularly in irrigation farming are recognized by policymakers at the international level. Hence, it is essential to give more attention in policy design and implementation strategies of SSI practices to be gender friendly to be in line with equity principle of sustainable development. Otherwise in the situation of gender inequality, all development efforts that on-going in Ethiopia are just like clamping with one hand (Yohannes and Gebrerufael, 2016). Thus, attaining the goal of sustainable development can be facilitated by addressing the gender gap in the participation of the community in different sectors including agriculture.

Moreover, sustainable development relies on the adequate availability of environmental resources such as water and land, which are key resources for irrigation. Based on the data obtained from FGDs, scarcity of irrigation water is one of the critical challenges that has constrained the benefit of SSI on sustainable basis during chronic drought seasons as the rivers dry and the volume of Lake Ziway shrank. Getnet *et al.* (2014) further elaborated this situation in the area as they reported increased evapotranspiration consumed $207 \text{ Mm}^3\text{yr}^{-1}$ more water (1990-2007) of lakes and land surface in CRV of Ethiopia. These authors also reported the trend of increasing water abstraction for irrigation purpose from ± 20 to $285 \text{ Mm}^3 \text{ yr}^{-1}$. Therefore, priority should be given on how to provide sustainable source of irrigation water for smallholder farmers even during severe drought situation and other extreme climate change and variability context to maximize the benefit that has to be generated from irrigation. Lefore, Giordano, Ringler & Barron (2019) also noted that the

poor performance of irrigation institutions restrict the resource-poor farmers' access to natural resources and it might lead to serious environmental degradation, which affects the sustainability of irrigation based livelihoods. Moreover according to Hansen *et al.* (2004), the application of climate information on how to manage risks in agricultural system among vulnerable rural communities and within a range of institutions is important to avoid the damaging effects of drought and other climate variability induced challenges.

Small irrigable landholding is the other factor that constrain the role of SSI on HHs' income and its benefit on sustainable basis. In the views of FGD participants at Shelad and Arata Chufa SSISs, farmers emphasized about the need for government's intervention to introduce pressurized irrigation system to increase the irrigable command area and beneficiaries rather than being simply dependent on gravity irrigation system. Awulachew (2019) highlighted that the Ethiopian government should work to provide equitable surface water access and expand sources of surface water during irrigation seasons by employing appropriate planning and basin-wide management. Moreover, increasing the fertility of the land is the other option that has to be taken into consideration to ensure the sustainability of the benefits of SSI. Feleke *et al.* (2019) reported that land degradation is one the serious threat that hinder the sustainability of irrigation based livelihoods in CRV of Ethiopia. Therefore, this has implication on the need to work on land fertility enhancing techniques to increase the productivity of the land and its contribution for improved HHs' income and sustainable development.

In the current study lack of financial capital found to be the other big constraint that hindered farmers' investment potential on SSI covering the high financial demand for fertilizer, pesticide, labour, improved seeds and the like. Financial capital directly affects farmers' decision to participate in SSI, the amount of HHs income and it has strong implication for sustainable development. Farmers participated in FGDs reported the inaccessibility of credit services for them and boldly noted this as their big challenge to pursue sustainable livelihood strategies. Although there are some credit services, farmers lack the willingness to take credit due to the fear of interest rate and ability to pay back the loan as farmers feel insecure whether they can gain or loss from their irrigated crop in the coming cropping season. Holden and Shiferaw (2004) emphasized that

the provision and adoption of credit can lead to increased grain production and improved household welfare. These authors also noted about the risks of taking credit. This has implication on the need to provide credit service with low or no interest rate to enable farmers to invest in irrigation without financial limitation to enhance the contribution of SSI to HH income and livelihood sustainability in drought prone areas. Yet, simple provision of credit might not bring the expected result in the livelihood of the farmers. Hence, farmers should be trained on how to use the loan taken to invest on sustainable income generating activities including SSI and other livelihood strategies that enable them to cope up unexpected climate variability and drought occurrences.

The finding of this research indicated that poor transportation infrastructural development constrained farmers' market access for agricultural input and output in both ATJK and Zeway Dugda districts. In our field investigation and in the discussion we had with farmers, transportation problem is more severe in Zeway Dugda district. Poor transportation service and the associated weak market linkage has strong negative effect on the income that has to be generated from selling irrigated products. FGD participants in Shelad SSIS complained a lot about the poor transportation infrastructure, which hindered them to have access even to the nearby district market. Consequently, most of the farmers lose the interest to invest on irrigation and even to quit irrigation. This implies that transportation and market access have strong effect on the income contribution of SSI, which directly affects the sustainability of rural livelihood development. Moreover, farmers' limited access for market gives opportunity for brokers to intervene between farmers and merchants. In such situation the brokers take the economic advantage at the cost of farmers' economic gain by fixing the price of irrigated products. FGD participants in both study districts noted that farmers feel highly peeved with acts of brokers as they are aware of the high economic gain of the brokers from their irrigated products. In line with this, farmers' strongly underlined the need for government intervention to control the role of brokers through the provision of farmers' cooperatives for marketing agricultural inputs and outputs. Generally, governments should bear attention on transportation infrastructural development and market access together with the introduction of productivity enhancing technologies. Otherwise, the agricultural technologies failed to contribute for short term economic gain let alone to contribute for sustainable development and livelihood sustainability.

2.6 Conclusion

Many complex and interdependent factors determine farmers' decision to participate in irrigation. Among the determinants, poor market access due to road problems found to be among the big constraint that negatively affect farmers' decision to participate in irrigation. Thus, it is impossible to increase farmers' participation in irrigation unless the problem of market linkage are solved by constructing suitable roads to transport the highly perishable irrigated vegetables. Having access to irrigable land is among the key determinants that influence farmers' decision to participate in irrigation. However, sometimes farmers don't participate in SSI due to the inability to cover high costs of inputs for irrigation farming. Thus, input provision needs attention to enhance farmers' participation in irrigation. Without significant short-term production and/or income gains, farmers may not consider their participation in SSI to be worthwhile. Without long-term benefits, sustainability will be compromised.

The analysis of the Heckman two-step outcome model result indicates that the amount of HH income is affected by different factors. Farmers' participation in irrigation affects HHs' income positively and significantly. However, the effect of irrigation on HH income is failed to ensure the sustainability of rural livelihood in the study districts particularly in some severe drought situations like the drought in 2015/16 in the area, both irrigation users and non-users were under government food aid. This implies that the existing SSI couldn't be the only viable solution to enhance the HHs' economy during chronic drought seasons to pursue sustainable development. Lack of adequate irrigation water in all seasons, small irrigable land holding, lack of credit service, degradation of the fertility of farmland, poor transportation infrastructure, weak market linkage, and gender inequality in generating income from irrigation entangled the role of SSI to contribute for sustainable development and livelihood sustainability. Therefore, it is plausible to introduce and accustom drought-resistant crops in drought-prone areas, promoting a pressurized irrigation system instead of a gravity system, provision of gender-friendly irrigation technologies and working on soil and water conservation tasks to enhance the sustainable benefit from SSI. Moreover, farmers have to diversify their livelihood strategies like livestock rearing, non-farm activities, and the like. In line with this, the role of extension service is very essential to support farmers to diversify their livelihood strategy. Yet, the extension service provision is poor in the

study sites. Hence, extension and communication services should be improved to enhance the sustainability of agricultural productivity in both irrigation and rain-fed farming systems.

Chapter 3: Effects of small scale irrigation on soil

This chapter is submitted to the journal for publication as:
Soil salinity problems, effects and ameliorative measures in small scale irrigation in Ethiopia:
Empirical evidence from the central rift valley of Ethiopia (accepted, Ethiopian Journal of
Biological Sciences).

Abstract

Soil salinity is an environmental threat that impedes productivity of irrigated crops particularly in arid and semi-arid areas. This research aims to assess the extent, causes, effects and ameliorative measures of soil salinity in irrigated fields in Central Rift Valley of Ethiopia. Composite soil samples were collected from farm plots that are irrigated using borehole and river water sources; soils samples were also collected from farm plots that have never irrigated (used as a control). Parameters including pH, EC, CEC, ESP, SAR, Exch.Na, bicarbonate, and Sum of Anions of the sample soils were analyzed. A composite water samples from boreholes and rivers were collected and pH, EC, TDS, Na, K, Ca, Mg, Cl, B, SO₄ and CO₃ were analyzed. Farm plots irrigated with borehole water characterized with sodic soils having Exchangeable Sodium Percentage (ESP) >15. Sodidity adversely affected growth of vegetables, land productivity and household economy. In this research household survey, focus group discussion and interviews were used to conduct social survey. The result of household survey indicated that farmers practice multiple soil salinity ameliorative techniques. The results of the social survey indicated that farmers lack knowledge, skills and capitals about the application of various ameliorative measures of soil salinity. Therefore, it is possible to enhance the sustainability of irrigated farming by conducting irrigation water monitoring, planting salt tolerant crops, designing environmentally friendly irrigation practices and empowering farmers on farming practices that can mitigate salinity.

Keywords: Soil salinity, sodicity, small scale irrigation, Central Rift Valley, Ethiopia

3.1 Introduction

Soil salinity is one of the serious environmental stressors that happened due to the mismanagement of irrigation and aridity (Bouksila *et al.*, 2013; Valipour, 2014). The total global salt-affected soil including saline and sodic soils was 831 million hectares based on the FAO's report in 2000 (Martinez-Beltran, 2005). The productivity of nearly 20-30 million irrigated hectares has been significantly decreased and about 0.25-0.5 million hectares of land lost each year globally due to salinity (FAO, 2002). Soils can be saline due to many factors such as weathering of parent materials, irrigation water, fertilizer, and shallow groundwater (Shahid, 2013). Salinity has afflicted crop production in irrigated regions of the world particularly in arid and semiarid areas where evapotranspiration exceeds annual precipitation, and irrigation is necessary to meet crop water needs (Datta & De Jong, 2002).

The high salinity level of irrigation water can adversely influence agricultural yield in quantity and quality, the sustainability of the soil for irrigation purposes, and the performance of the irrigation system (Gebrehiwot, 2018). Irrigation is considered as a vital tool to improve the subsistence-oriented rural farm households' economy to assure food security in Ethiopia (Hagos *et al.*, 2009). Accordingly, irrigation has been expanding among smallholder farmers particularly in semi-arid and arid parts of the country where drought and erratic nature of rainfall are prevalent like the Central Rift Valley (CRV) of Ethiopia (Feleke *et al.*, 2019; Yihun, 2015). However, irrigation has been criticized for its negative environmental effects among which soil salinity and waterlogging found to be critical problems, which impede the productivity of irrigated farm plots (Gebrehiwot, 2018; Zewdu *et al.*, 2017). Over the last 30 years, intensive cultivation and land degradation have increased in the CRV of Ethiopia (Meshesha *et al.*, 2012). The accelerated land degradation condition in the area has far-reaching ecological and socio-economic consequences. According to Zewdu *et al.* (2017), long term irrigation would affect the agricultural potentiality of an area. Irrigated agriculture in the arid and semi-arid areas such as in coastal environments and the CRV are becoming increasingly threatened by salinity due to using groundwater for irrigation (Datta & De Jong, 2002; Zewdu *et al.*, 2017).

In Ethiopia, the total land area covered by salt-affected soil is estimated to be 11,033,000 hectares. Such areas are mainly found in the rift valley zone, where groundwater has been used as a source of irrigation water (Seid & Genanew, 2013). The decline in the quality of the soil in irrigated farm plots at CRV of Ethiopia was reported by (Ulsido *et al.*, 2013). Concerning the reclamation of salt-affected soils, sodic soils usually are the most expensive to reclaim and, in many situations, reclamation is not economical (Geen, 2015; Horneck, Ellsworth, Hopkins, Sullivan, & Stevens, 2007). The choice of an amendment and its relative effectiveness is judged from the improvement of soil properties Kefyalew & Kibebew (2016) and crop growth and the relative costs involved (Abrol, Yadav, & Massoud, 1988). Abrol *et al.* (1988), Geen (2015) and Horneck *et al.* (2007) emphasized that to be successful in the reclamation of sodic soils cropping must be preceded by the application of chemical soil amendments followed by leaching for removal of salts derived from the reaction of the amendment with the sodic soil.

Few studies are already available related to assessing the soil salinity situation in irrigated plots in Ethiopia, for instance (Gebrehiwot, 2018; Kefyalew & Kibebew, 2016; Mulat, Ashenafi, & Gezai, 2018; Zewdu *et al.*, 2017). Yet, there is no study, which addresses soil salinity problems in irrigated farm plots incorporating laboratory analysis of soils and irrigation water sources and social surveys in the study sites. Thus, we believed that understanding the soil salinity status and irrigation water quality plays a significant role to map the spatial distribution of salt-affected soils and to determine the type of salinity. Such information is highly valuable for policymakers and development practitioners to design better policies and development intervention that targets sustainable irrigation-based livelihood in drought-prone areas, where irrigation does not option rather mandatory to overcome the effects of recurrent chronic drought.

According to Van Halsema *et al.* (2011), any strategy that targets to increase irrigation efficiency in CRV should include interventions to improve crop productivity and economic returns from small scale irrigation (SSI). Moreover, this study has a significant contribution to provide information for land reclaiming options and decisions on soil amendment in irrigated fields to sustain the farmers' benefit out of SSI in the study sites, where rain-fed agriculture is highly vulnerable to extreme rainfall variability causing crop failures and food insecurity. Therefore, the aim of this research was to (1) determine the salinity status of the soil; (2) identify the factors that

affect soil salinity development, and (3) explore the effects of salinity and ameliorative measures to mitigate the problems of soil salinity.

3.2 Study design and analysis

3.2.1 Study area identification and selection: GIS based

Adami Tulu Jido Kombolcha (ATJK) and Zeway Dugda districts (Woredas) were selected as study sites purposely. The reason for selecting these two districts is that their long time experience in SSI practices to overcome the effect of drought and erratic nature of rainfall. Some studies showed that climate risk quantified in terms of drought frequency revealed that all the districts in the CRV experienced drought ranging from 2 to 5 times within 33 years (Gizachew & Shimelis, 2014). The same authors reported that ATJK and Zeway Dugda were two of the districts among the worst hit districts by chronic drought and experienced the highest frequency of droughts (5 times in 33 years). Gizachew & Shimelis (2014) further noted that ATJK and Ziway Dugda districts had the highest probability of severe drought occurrence with 46 to 76% severity level in East Shoa zone of Ethiopia. The two districts are characterized with the occurrence of extreme rainfall variability, food and nutrition insecurity, safety net dependency and long experience in SSI practices. In 2016/17, there were 136,329 and 58,000 people who received relief assistance food aid in ATJK and Zeway Dugda districts respectively (ATJK and Zeway Dugda districts' Disaster Risk Management Office (DRMO), 2017). Such climate risk factors makes irrigation a necessity than option. Thus, SSI has been expanding in the area and we are interested how SSI is operating/performing in the area focusing on investigating soil salinity, its effect and remedial measures.

After the identification of the study districts, Google earth exploring supported with field based assessment, sampling sites were selected and the land use polygons were created by digitization technique. The polygon of river water irrigated, borehole water irrigated and rain-fed grid is saved as KML and converted to layer in ArcGIS and then the polygon is exported to shape-file. Accordingly, soil sampling sites were selected depending on agricultural land use of the site and farming practices that takes place in the area after discussing with the farmers in the study site supported with GIS based field assessment as shown in Figure 3.1.

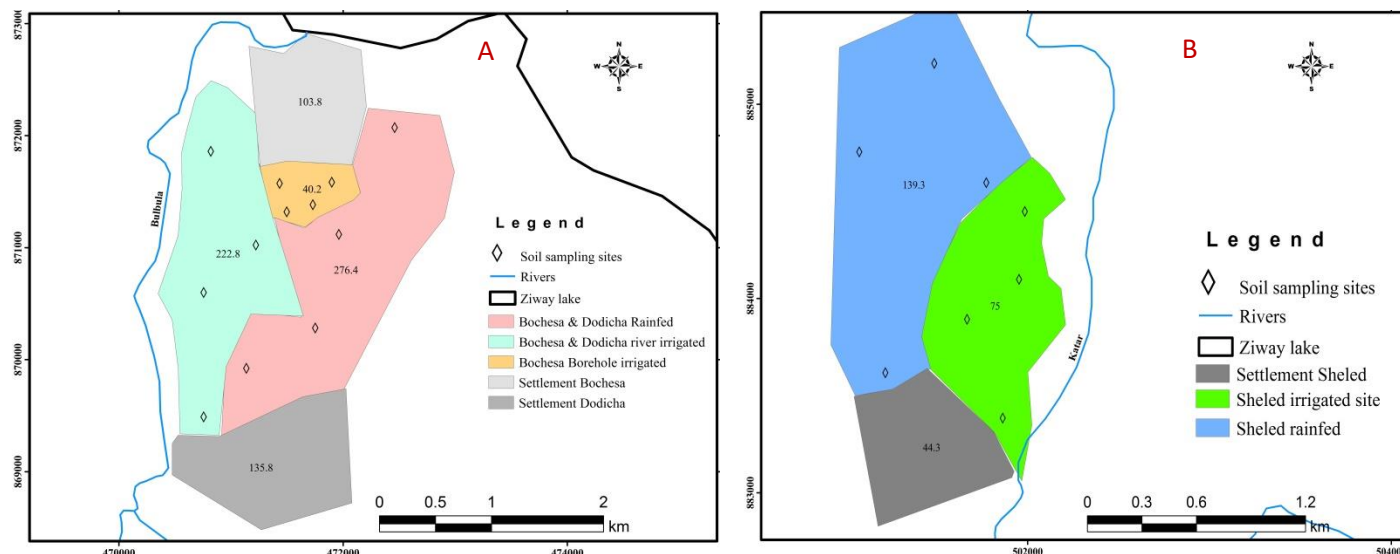


Figure 3.1: Soil sampling sites (A⁴& B⁵)

3.2.2 Soil Sampling

Soil samples were collected from the irrigated farms that use water from rivers (Bulbula and Ketar rivers) and boreholes and from farms that has grown crops only by rain (Bulbula farm and Ketar farm). First, the top layer of soil or the organic part of the top layer (debris of plants, living organisms and others) was removed. Then, digging the soil 0-15cm by shovel and dispatch soil from different soil layer, put the soil sample in clean container and repeat this process four times to make a single composite sample of one kilogram as shown in Figure 3.2. Then, the soil samples are collected in clean plastic bag with correct labeling which includes sampling date, sampling depth, site name, sample collector and GPS points. Then, the same soil sampling techniques were used to take sample from 15-30cm depths. For both soil layers, samples were taken as a replica as shown in Figure 3.2 and they are thoroughly mixed and composite sample is taken into the laboratory for chemical analysis with care. A total of 40 soil samples were taken for laboratory analysis.

⁴ is the soil sampling site at Bulbula river and borehole irrigated sites at Bochessa and Dodicha

⁵ is the soil sampling site at Ketar river irrigated sites at Shelad



Figure 3.2: Soil sampling techniques at different depth

3.2.3 Water sampling sites and procedures

GIS based water sampling sites were selected as shown in Figure 3.3. Water samples were collected from two types of sources involving the borehole and surface water from upper part of Ziway lake (Ketar river) at Sheled and lower portion of the lake (Bulbula river) at Bochesa and Dodicha sites. The water samples were collected during the pick irrigation season as the main focus of this research is to examine the effect of irrigated farming on soil salinity during the dry season in which there is a high demand for irrigation water application. Irrigation water samples from Borehole water should not be collected until the well has pumped for a period of one or two hours. Borehole water lifted up by generator power and collected as pond which transferred to soil as soon as collected not stored (Figure 3.4). While it is pumped out to the pond within ten minute at different interval time six liter of water and homogenize and then take one liter of homogenized sample to the laboratory. River water was also pumped by generator power. The sample for the river water was taken from the source where pumping material was inserted and from the canal system. Eight liter of water was taken and then homogenizes and one liter was taken to the laboratory from the study sites. Clean plastic containers were used for taking the water sample into the laboratory. The plastic container was rinsed with the water being sampled before collecting the final sample. Then, four

water samples were collected from Ketar river at diversion point and its canal systems, four water samples were collected from Bulbula river at pumping sites and four water samples were collected from boreholes at Bochesa site (Figure 3.3). Finally, the samples were thoroughly mixed and composite samples were used for each water source separately and a total of 12 water samples were taken for laboratory analysis. The area irrigated by each water source are 40.2, 222.8, 75 hectares by Boreholes at Bochesa, Bulbula river at Bochesa and Dodicha and Ketar river at Sheled respectively.

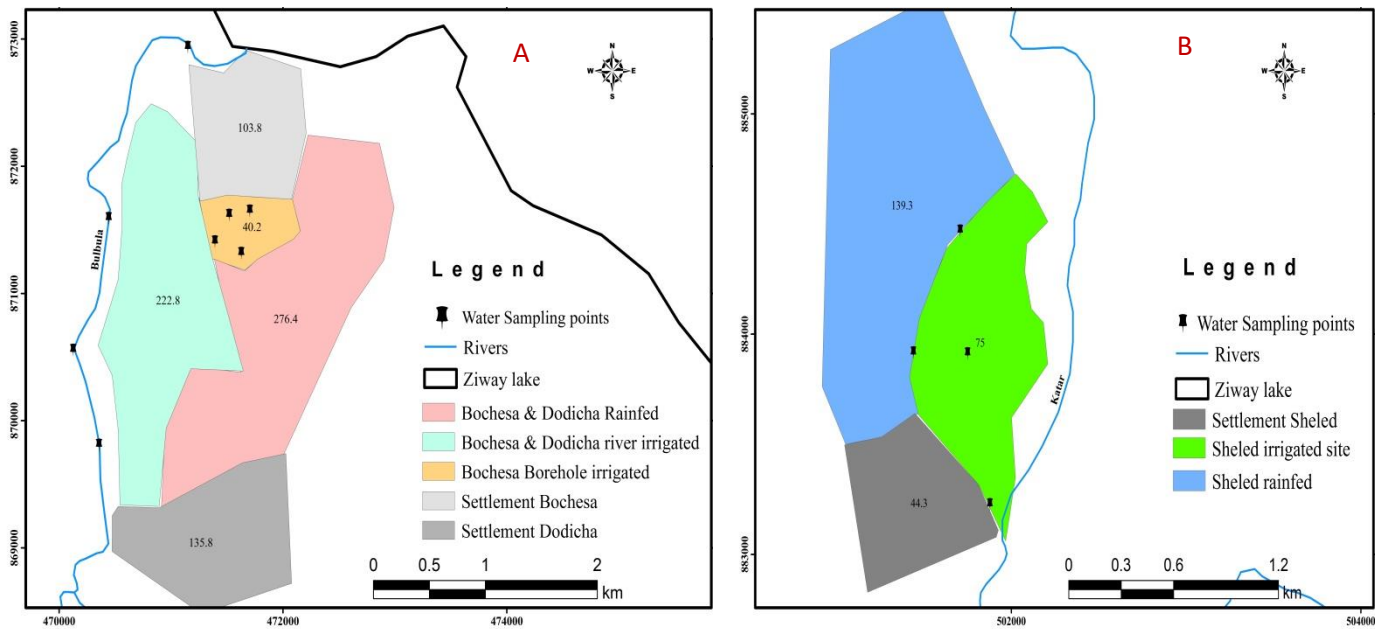


Figure 3.3: Surface and ground water sampling sites (A⁶ & B⁷)

⁶ is water sampling sites at Bulbula river and boreholes

⁷ is water sampling sites at Ketar river and its canal systems



Figure 3.4: Water sampling techniques at different sources

3.2.4 Soil and water laboratory testing methods

Soil laboratory testing methods

The laboratory analysis of soil and water was performed in Ethiopian Water Works and Supervision soil and water laboratory following all the necessary procedures of a standard laboratories and using different testing methods. Prob method was using to test the pH-H₂O and pH-KCL of the soil samples. In testing the chemical characteristics of soil samples ammonium acetate method was used for testing the parameters such as EC, Exch.Na, Exch.Ca, Exch.Ma, CEC, and Exchangeable Sodium. Besides, volumetric and instrumental testing methods were used to test the parameters of soluble salts (Paste Extract) such as EC_{sat}.Ext., Na, K, Ca, Mg, CO₂, HCO₃⁻¹ CL-1, SO₄⁻² and Sodium Adsorption Ratio (SAR).

Irrigation water laboratory testing methods

In the analysis of the quality of irrigation water, the concentrations of major cations of Calcium (Ca²⁺), Magnesium (Mg²⁺), Na⁺, and K⁺ were measured using a direct-current plasma spectrometer (DCP) calibrated using solutions prepared from plasma-grade single-element standards. Major

anions of Chloride (Cl⁻), and Sulfate (SO₄²⁻) were analyzed using an ion chromatograph(IC). Total alkalinity (TA) was measured using titration techniques. The concentration of Boron (B) in the irrigation water was tested using ammonium acetate method. Total dissolved solid (TDS) was analyzed using Pocket Pro TDS Tester, low range.

3.2.5 Methods of data analysis

SPSS and Excel software were used for analysis of the result such as ANOVA and tested with least significant difference (LSD) test at an alpha ($\alpha/2$) of 0.05 to differentiate the variables or the parameters significantly different in terms of its composition and effect. We do an LSD test at 95% confidence interval using SPSS software. Then, the decision can be non-significant (NS) which shows the observed difference between the soil sample means is not convincing enough to say that the average parameters measured differ significantly, significant (S) which shows the observed difference between the soil sample means is convincing enough to say that the average parameters measured differ significantly and highly significant (HS) which shows the observed difference between the soil sample means is convincing enough to say that the average parameters measured differ at a high significance.

After the laboratory analysis of water sample, Sodium adsorption ratio and ESP was computed using the following equations:

$$\text{SAR} = \frac{[\text{Na}]}{\sqrt{\frac{[\text{Ca}] + [\text{Mg}]}{2}}} \quad \text{Equation 1 (Hanson } et al., 1993)$$

$$\text{ESP} = \frac{1.475 \times \text{SAR}}{(1 + (0.0147 \times \text{SAR}))} \quad \text{Equation 2 (Hanson } et al., 1993)$$

Equation 1 and equation 2 are used to calculate the SAR of surface irrigation water. For groundwater and soil water, the SAR may need to be adjusted to account for calcium carbonate solubility. According to (Hanson *et al.*, 1993), the actual calcium concentration of the soil water may actually be higher or (more frequently) lower than the Ca concentration of the irrigation water. Hence, actual calcium concentration of the soil water is taken from taking EC versus the bicarbonate to calcium ratio (Hanson *et al.*, 1993). Descriptive statistical techniques were applied to evaluate the relative abundance of the salinity problem due to different irrigation water quality status and between the rain-fed and irrigated component of the study area.

N-vivo11 software was used to analyze FGDs, and interviews. The interaction between irrigation water quality, soil situation (comparing irrigated with rain-fed farmland), and their implication for agricultural resources and agricultural sustainability in the future in the study area are discussed. The HH survey data were analyzed using SPSS software. Finally the recommended measures are forwarded to reclaim the affected soil and what is going to be done not to increase the problem further due to the effect of irrigation.

3.3 Results and discussions

3.3.1 Soil chemical characteristics

Laboratory analysis was done for 22 parameters, then we have selected 8 parameters once we run correlation coefficients among the 22 parameters. Hence the parameters such as pH-H₂O, Exch. Na, EC, CEC, Bicarbonate, the sum of anions, ESP, and SAR are used for analysis (Table 3.1). Regression analysis was done to examine whether there is difference in the measured soil parameters based on soil depth of 0-15cm and 15-30. The result of the regression analysis showed that that there is no significant influence of depth of soil on different parameters of the soil; this needs further investigation to verify the result how there is no difference in the parameters based on depth of the soil. Hence, the average values of those parameters is used for analysis purposes and the chemical composition of soils irrigated from different sources are presented in Table 3.1. Using the results of these parameters, we run the Analysis of Variance (ANOVA) test to examine differences in the concentration of different soil samples taken from farm plots irrigated using different irrigation water sources and rain-fed plots. The analysis of variance (ANOVA) revealed that there is a highly significant difference between the groups of different irrigation water sources for the parameters such as pH, EC, ESP, and Exchangeable Na.

Based on the ANOVA result the difference in soil parameters was tested with the least significant difference (LSD). The decision on the significance level is done as not significant (NS) with the level of significance > 0.05 , significant (S) with the level of significance < 0.05 but >0.01 , and highly significant (HS) with the level of significance < 0.01 . With regard to pH-H₂O, Ex.ch.Na,

ESP and EC, soil samples irrigated with groundwater has no significant difference with areas irrigated with River Bulbula. This similarity in the result might be due to geographical proximity in which the soil samples irrigated by groundwater and Bulbula River found in the Lake Zeway sub-basin and existing farming practices are similar, which can affect the result of the finding.

Table 3.1: Chemical composition of soils irrigated from different sources of water

Sampling site	pH-H ₂ O(1:2.)	EC(ms/cm) (1:2.5)	CEC (meq/100gm soil)	Exch.Na (meq/100 gm of soil)	ESP	SAR	Bicarbo nate	Sum of Anions
Soil sampled from Irrigated part of the study area								
Ground water	9.3	0.35	56.895	16.845	29.7	3.11	7.03	32.72
Bulbula river	8.515	0.1875	49.2925	6.415	13.5	1.37	7.1275	16.13
Ketar river	7.815	0.2975	67.365	3.25	4.9	2.16	1.5325	7.54
Soil sampled from rain-fed part of the study area								
Rain-fed (along Bulbula)	7.4275	0.0725	54.76	3.787	6.98	0.78	5.6925	13.24
Rain-fed (along Ketar)	7.865	0.345	68.59	3.98	5.82	3.11	2.18	7.27

However, there is a highly significant difference in the pH-H₂O, Ex.ch.Na, ESP and EC between groundwater and samples irrigated by Ketar and rain-fed farm plots. Yet, no significant difference is found between these parameters among the soils irrigated by Ketar and rain-fed farm plots as it is shown in appendix III. This difference in the parameters have its own implication on the status of soil salinity.

3.3.2 Chemical characteristics of irrigation water sources

The current study revealed that the irrigation water that falls with the value of SAR > 15 and Adjusted ESP >13 at EC < 4ds/m indicates the sodic nature of the water. Water with such high SAR of soil water at all sources which will create a hazardous condition to the osmotic potential of the plant which influences plant nutrient and water uptake in the soil that in return affects the

productivity of the soil that initiates a search for the immediate solution of all stakeholders. The data on table 3.2 indicated the chemical concentration of irrigation water sources, which were collected during the pick irrigation season (dry season) Water chemical concentration value varies across seasons.

Table 3.2: Chemical characteristics of irrigation water sources in the study area

Source of Sample	Groundwater	Bulbula river	Ketar river
pH	7.92	7.515	6.68
T.Dissolved Solid 105°C(mg/l)	1338	367	132
Sodium(mg/l Na+)	520	83	20
Potassium (mg/l K+)	44	36.5	10
Total Hardness (mg/l CaCO3)	124	135	60
Calcium (mg/l Ca2+)	25.6	23.2	16
Magnesium (mg/l Mg2+)	14.4	18.18	4.8
Alkalinity (mg/l CaCO3)	1035.54	250.27	100.98
Bicarbonate (mg/l Bicarbonate)	1263.36	305.58	123.2
Chloride(mg/l Cl-)	82.05	17.13	4.69
Sulphate (mg/l Sulphate)	20.87	23.315	8.5
ESP	63.3	21.22	8.4
SAR	116.28	18.255	6.2
Boron (mg/l B)	Trace	Trace	Trace
Carbonate (mg/l Carbonate)	Nil	Nil	Nil
HCO3/Ca	49.35	13.48	7.7
EC(ds/m)	1.973	0.5305	0.19
Equilibrium Ca concentration	0.22	0.385	0.5
Adjusted SAR	272	38.75	17.4
Adjusted ESP	80.27	37.31	20.41

3.3.3 Classification of soil salinity

The current study revealed that there are three categories of farm plots irrigated by different water sources based on Exchangeable sodium (Na). In the first category, groundwater irrigated areas have significant and highly significant differences with other areas irrigated with all sources. The second category farm plots irrigated by the Bulbula River have a significant difference with groundwater irrigated areas and highly significant difference with areas irrigated by River Ketar and rain-fed farm plots. In the third case River Ketar, irrigated areas, and areas under rain-fed have

similarities with one another while highly significant differences with the aforementioned categories.

Hence, high salinity/sodicity development is expected in those first and second categories for the exchangeable sodium (16.845 meq/100gm of soil) in areas irrigated with groundwater followed by areas irrigated by Bulbula river with exchangeable sodium (6.735 meq/100gm of soil) while it is quite low in other sampling areas which are supported by scholars (Etissa, Dechassa, Alamirew, Alemayehu, & Desalegne, 2014). But, it is still developing though it is not significant. The salinity status of the soil in the study area is summarized and discussed based on the criteria presented by Geen (2015) and Horneck *et al.* (2007) as shown in Table 3.3. The decision on salinity is presented in appendix IV. The main sources of soil salinity and sodicity development are groundwater based irrigation. The driving force for upward movement of water and salts is evaporation from the soil plus plant transpiration (Gebremeskel *et al.*, 2018). But, Gebrehiwot, Tadesse, Bheemalingeswara, and Haileselassie (2011) found low SAR in groundwater samples in Tigray, Northern Ethiopia. This implies that different factors including that of parent material, geographical location and climate factors in affecting the development of soil sodicity.

Table 3.3: Properties used to classify salt affected soils

Profile code	Groundwater irrigated	Bulbula river irrigated	Ketar river irrigated	Rain-fed (around Bulbula)	Rain-fed (around Ketar)
pH-H₂O(1:2.5)	>8.5	>8.5	<8.5	<8.5	<8.5
EC(ms/cm)(1:2.5)	<4	<4	<4	<4	<4
ESP	>15	<15	<15	<15	<15
Soil salinity classification	Sodic soil	Non salt affected	Non salt affected	Non salt affected	Non salt affected

According to Horneck *et al.* (2007 and Mulat *et al.* (2018), soils with >15 ESP have a high sodicity risk due to the effects of Na on soil structure and toxicity to crops. Gebremeskel *et al.* (2018) further noted sodicity problems apparent at higher relative Na⁺ concentration and lead to degradation of soil structure. Accordingly, the soils of the area irrigated with groundwater which has (ESP = 29.7) as shown in Table 1 is classified as sodic soil while the soil of the area which is irrigated by Bulbula river has also been developing sodicity as its ESP value is nearest to the

upper limit $13.515 \approx$ nearest to 15). This implies that those areas irrigated by groundwater are Sodic (Alkaline) soils show the effect of groundwater on the development of sodicity in the area with high ESP. The study indicated that the sodicity problem can be expected in the long run in areas irrigated with the Bulbula River.

The research undertaken by Seid and Genanew (2013) has a similar finding who reported the existence of sodicity both in the soil and in irrigation water sources in the study conducted at the Fursa SSI system in Awash River Basin. This implies those areas with sodic hazards need urgent attention to awareness creation and reclamation interventions. Understanding the type of sodicity has also a paramount importance for proper reclamation activities. To this effect, the type of sodicity developed due to the irrigation of groundwater was also determined based on Dierickx, (2000). It is found that the type of salinization in the groundwater irrigated portion has a Sodium-Calcium type, which is marked by Na/Mg ratio is >1 , Na/Ca ratio is <1 and Mg/Ca ratio is <1 , indicating the presence of high exchangeable sodium compared to calcium and magnesium (Horneck *et al.*, 2007).

3.3.4 Sources of soil sodicity

The current study revealed that multiple factors found to be the causes for the development of soil sodicity in the study sites such as the sodic nature of irrigation water sources, intensive use of chemical fertilizer, waterlogging, and lack of appropriate drainage systems in irrigated farmlands. Our soil and water laboratory analysis showed that Borehole irrigated farm plots found to be under high risk of soil sodicity ($ESP > 15$) development at Bochessa site as can be seen in Table 3.3. Among the surface water sources, farm plots irrigated by the Bulbula river showed higher ESP greater than farm plots irrigated by Ketar and rain-fed plots as presented in Table 3.3. A study by Ulsido *et al.* (2013) showed that the source of salinity is not a natural weathering process rather soil salinity is developed due to irrigation water.

Moreover, time plays a critical role in the formation of sodic soils. The development agents (DAs) interviewed in the KII confirmed that borehole irrigation water sources as the major cause for soil sodicity formation in the Bochessa site. The participant further noted that the sodicity of the soil

has been increasing from time to time due to intensive irrigation on-farm plots. According to the KII with the head of agriculture and rural development office at ATJK district, the sodic nature of boreholes and Bulbula River is further aggravated due to the release of wastewater from private large scale floriculture and horticulture irrigation farms that are found around Bulbula and Lake Ziway. Thus, wastes from this large scale irrigation farms affect the quality of the irrigation water and consequently affected the quality of the soil irrigated from such water sources.

On the other hand, the result of this study indicated that the type of soil in the irrigated fields is also a driving factor for soil salinity problems at Shelad SSI site. Gebremeskel *et al.* (2018) support our finding reporting that the main factors that control sodicity problems are soil type. The KII conducted with irrigation expert at Ziway Dugda district confirmed that the main problem for waterlogging and associated soil salinity development is the type of the soil being Vertisol. The expert indicated that irrigation has a long history in Shelad around 44 years back including the traditional irrigation schemes. The earthen canal was constructed using soil, which was brought from the other area. So, after a long time the soil removed from the canal during cleaning the canal and the Vertisol soil appear and causing waterlogging due to the swelling and shrinkage nature of the soil which causes the water to percolate under the canal through cracks and returned to surface in the farm field in the form of capillary action. The process of returning to the surface during dry season creates unnecessary waterlogging in the farm and causes loss of the land and development of salinity as a leftover when the land is dry as shown in Figure 3.6. The KII participant also underlined that the irrigation system is not good in its outlet to return the water into the river rather the water remains in the farm field (Figure 3.5).



Figure 3.5: Waterlogged areas, which were previously farm lands at Shelad site

Some previous studies reported the specific limitations of irrigation water quality from various sources in central rift valley (Koka Lake, Borehole around Ziway, Ziway Lake, etc). For instance, Etissa *et al.* (2014) stated that sample of groundwater from Dugda Borra district was not fit for irrigation as it did not meet water quality standard for irrigation purpose due to high salt contents, chloride toxicity, too high pH, and high contents of bicarbonate and calcium ions. The interrelation between sodicity and salinity levels in irrigation water or water coming through capillary flux from groundwater introduces a dual problem in terms of crop response, soil structure degradation, and irrigation management (Gebremeskel *et al.*, 2018).

3.3.5 Effect of soil sodicity

The laboratory result of soil sodicity development in borehole irrigated farm plots are further verified by the interview results in which farmers use some indicators to justify the development of sodicity on their farm plots. The identified indicators include changing in the color of the soil into a dark, deposition of white salt looking surface on the soil, reduction in water holding capacity of the soil, and increasing demand of irrigated plots for frequent watering. According to farmers' view, sodicity affects yield in irrigated fields through hindering the appropriate growth of vegetables and seedlings, reduce the productivity of land and water and negatively affects the economy as farming in lands affected by sodicity demands high human labor, chemical fertilizers

and frequent irrigation (Table 3.4). The finding of Gebremeskel *et al.* (2018) confirms our result stating that high levels of sodium in groundwater result in an increase of soil sodium levels, which affects soil structural stability, infiltration rates, drainage rates, and crop growth potential. Moreover, our study showed that the tolerance of vegetables to soil sodicity effects are different, for instance, farmers pointed out that cabbage and tomato are less tolerant to the effects of soil sodicity though soil sodicity affects the growth of all plants. Similar to our findings, Qureshi & Al-Falahi (2015) indicated that farmers perceived the loss of farmland due to salinity as a challenge for their agricultural productivity.

According to Gebremeskel *et al.* (2018), the effects of sodicity-salinity on the physical and hydraulic properties of the soil are very complicated processes that can be influenced by many factors. The current study showed that the adverse effects of sodicity are further aggravated due to the problem of the declining trend of soil fertility. The household interview participants at Dodicha SSIS confirmed the severity of soil quality deterioration in irrigated fields than rain-fed lands. For instance, farmers verified stating that they cannot produce irrigated vegetables (tomato, onion, cabbage, etc.) without applying chemical fertilizers owing to the deterioration of soil fertility. Household interview participants in all study sites indicated that in the past they were using 25kg of chemical fertilizer for 0.25ha of land, but now they are using 100kg or 150kg of fertilizer for 0.25ha of land. In association with this farmers complained that working in SSI increases their costs for chemical fertilizers, pesticides, and herbicides. A similar result on the reduction of land productivity in irrigated fields in the rift valley lakes basin was reported by Ulsido *et al.* (2013). The high cost of fertilizer is a challenge of irrigators in Sub-Saharan Africa due to deterioration of soil quality (Mwamakamba *et al.*, 2017). Furthermore, based on the information obtained from KII with an agronomist at Shelad site about 12ha of land, which is the landholding of 50 HHs were lost as it was affected by waterlogging. The key informant noted that the farmland becomes marshy and saline, as a result, the area became out of production and serve as livestock grazing land.

The effects of sodicity in the study area are much diverse and persistent which includes the effect on soil quality, vegetable growth, and maturity (Figure 3.6), water quantity, the yield of vegetables and crops and economic cost rise (labor demand increase and household economy affected) due to several factors as shown in Table 3.4. According to Bauder *et al.* (2014), sodicity causes a decrease

in the downward movement of water into and through the soil, and actively growing plant roots may not get adequate water, despite pooling of water on the soil surface after irrigation. Furthermore, according to Abrol *et al.* (1988), sodicity lowers the permeability of the soil to air and water, lowering the availability of some essential plant nutrients due to the osmotic effect of the salt and causes specific ion effects (toxicity).



Figure 3.6: Effect of Sodic water on soil and vegetation growth

A study by Bauder *et al.* (2014) also describes that the quality of irrigation water available to farmers and other irrigators has a considerable effect on what plants can be successfully grown, the productivity of these plants, and water infiltration and other soil physical conditions. In the study area, we have found similar results which are manifested by a reduction in yields, early drying of seedlings, an increase in the irrigation water requirement for the same yield, and failure of some crops due to their low salt tolerance level. Therefore, this has implications for constraining smallholder farmers' livelihood, which in turn affects their food security status. Soil salinization is one of the major constraints in achieving food security in Ethiopia (Asad *et al.*, 2018).

Table 3.4: Effects of soil sodicity: Farmers' view

	Effects of salinity	No. of household interviews
Soil	The soil gets dry Cracking forms on the farmland The farmland become very black and hard to plow Plowing land affected by salinity is difficult Deposition of ash type of salt looking surface on the soil	12
Vegetables	Seedlings dry Wilting of crops or vegetables before flowering Poor growth of vegetation (yellow color of vegetable leaves like tomato shown in Figure 7)	15
Water	High irrigation water consumption due to sodicity which increases the frequency of irrigation	8
Agricultural yield	Yield of irrigated vegetables declines though the fertilizer amount applied is increasing from time to time	16
Economic cost rise (Labour demand increase and Household economy negatively affected)	Demands much human labor for frequent plowing and irrigation Demands high financial capital for additional chemical fertilizer Needs frequent plowing by oxen The land affected by sodicity was left to be open and the farmer rents the land from other farmers whose land is not affected by sodicity	13

Qureshi & Al-Falahi (2015) also emphasized that low land productivity in irrigation fields resulted in low farm income, food insecurity, and the prevalence of poverty. However, according to Mwamakamba *et al.* (2017), low productivity in irrigation fields might be also related to low-quality inputs such as seeds and others. This implies that many factors might impede the productivity of irrigation in addition to the decline in soil fertility due to sodicity. Therefore, considering many factors of production weighs more than focusing on single factors to enhance irrigated agricultural production on a sustainable basis. In general, the study showed that the declining trend of soil fertility due to sodicity and other factors could potentially undermine the poverty-reducing role of SSI sustainably. Therefore, there is an urgent need to averse the problem of sodicity and to recover the affected soil to enhance the sustainability of livelihoods dependent on SSI.

3.3.6 Remedial measures to ameliorate soil sodicity

Reclamation of sodic soils is mandatory in the study area which requires the removal of part or most of the exchangeable sodium and its replacement by the more favorable calcium ions in the root zone (Abrol *et al.*, 1988). This can be carried out in many ways that involve amendment or cropping pattern adjustment (Ezlit *et al.*, 2010). Farmers use different land reclamation techniques to recover soils affected by sodicity in the sites. As it can be seen from Table 3.5 an individual irrigation user farmer uses different soil sodicity ameliorative techniques. A total 259 irrigation user farmers were selected for the survey, accordingly these 259 irrigation users apply multiple (Table 3.5) sodicity ameliorative techniques to averse the adverse effects of sodicity on crop production and their HH economy. The majority of the farmers (93.8%) applied crop rotation as method to mitigate the effect of sodicity. The next highest number of farmers (87.3%, Table 3.5) apply higher high amount of chemical fertilizer when they observe the development of salinity in their farm land. The other relatively higher percentage of the respondents (64.9%) plowing their farm land repeatedly by oxen before planting to overcome the adverse effects of sodicity. Fallow the irrigable land (27%) and apply compost (32%) are practiced by less number of farmers. Based on the FGD conducted with farmers, they pointed out that fallow the land is not common practice to mitigate soil sodicity as farmers have small landholding. Besides, the FGD along with key informant interviewees recommended that farmers have to use compost rather than chemical fertilizer to enhance the fertility of degraded farmlands in the study sites. In the study area, there are trials of amendments and improvement of the farm field through the application of compost.

However, the FGD participants indicated that farmers in their area have a negative attitude towards using compost because of its labor-intensive nature, which needs much livestock, and the community believed that compost preparation might bring illness (*Michi*⁸) due to effect of methane gas in the compost. This implies that farmers should be technically supported in the process of making compost to ventilate using a tube ventilation system to remove the methane from the compost starting from the very beginning or before it is taken out from the pit and transported into the farm field for application. Irrigation user farmers also apply more irrigation water frequently

⁸ Amharic term referring illness due to methane effect on eye and respiratory systems

to mitigate the effect of salinity in farm lands. However, applying more water is difficult to practice due to the problem of water scarcity.

Table 3.5: Common soil sodicity ameliorative techniques practiced by farmers

Sodicity ameliorative techniques practiced by farmers	Farmers practicing the technique	Percentage
Cropping pattern adjustment (crop rotation)	243	93.8
Plowing the land repeatedly by oxen before planting	168	64.9
Apply more irrigation water frequently	99	38.2
Fallow the irrigable land for some cropping season	70	27
Apply compost	84	32
Apply higher amounts of chemical fertilizer than lands affected by salinity	226	87.3

Moreover, in the study area, the irrigation expert at Shelad site highlighted the need to use a lined canal to avoid the problem of waterlogging, salinity, and associated loss of farmland. Yet, the expert further noted the financial limitation of the district to upgrade the earthen canal into a lined canal. Based on the interview with an agronomist at the Shelad site, the application of gypsum is a recommended measure to reclaim salt-affected soils in the area. Yet, the key informant further noted that farmers couldn't afford the cost of gypsum and some of the farmers have low awareness about sodicity, its problem, and its amendment techniques. This implies that cost subsidy to gypsum has to be implemented to sustain the SSI activity in the study area by mitigating the problem of soil sodicity.

Generally, it is recommended to work on upgrading the existing schemes to improve the productivity of agricultural land and not to lose additional farmland due to salinity and waterlogging by introducing a sustainable and farmer-friendly land reclamation measures. Appropriate irrigation techniques have to be designed for the sustainability of soil productivity in irrigated farmlands (Seid & Genanew, 2013). National governments can involve promoting basic land reclamation and water monitoring by farmers (Mwamakamba *et al.*, 2017).

Therefore, capacity building and awareness creation activities should be done to increase farmers' knowledge and skill in applying sodicity amendment techniques including compost preparation and application, which is cheap and available in the area. Farmers should also be assisted with pieces of training and demonstrations at the farm field on how to reclaim the sodicity of their land using locally available materials without affecting their health. In such a way the attitude of the farmers can be changed to be positive towards organic soil sodicity ameliorating mechanisms. Furthermore, farmers should be supported to integrate the use of scientific (gypsum) and indigenous knowledge (crop rotation) to ameliorate the problem of soil sodicity. However, farmers mention the lack of attention for extension support on technical aspects to mitigate or avoid the effects of sodicity from their soil due to the weak implementation and management of the SSI project. Hence, supportive and strong extension service has to be introduced in the study sites to overcome the multiple livelihood challenges of irrigators and other farmers due to the problems of soil sodicity and other related problems.

3.4 Conclusions

Farmlands irrigated with boreholes found to have sodic soils that are in line with the chemical characteristics of the sodic type of the water as indicated by the laboratory test result in the Bochesssa site. Moreover, farm plots irrigated by the Bulbula River have high ESP value than farm lands irrigated by Ketar river and rain-fed farm plots. Based on the result of the laboratory analysis and view of the community, multiple factors affect the development of soil sodicity. Therefore, gypsum and crop-based land reclamation measures need to be implemented to averse the negative effect of sodicity on crop production to enhance the sustainability of the benefits of SSI in the area. On the other hand, waterlogging and associated sodicity development resulted in the loss of farmlands at the Shelad site due to poor drainage systems. Therefore, it needs urgent intervention to introduce a farmer-friendly drainage system to avoid further loss of farmlands and to sustain the benefit of SSI in the area. Hence, adopting rice and another salt-tolerant crop production system is mandatory in the waterlogged areas in addition to the gypsum amendment which is laborious to farmers while it is very economical and abundant in the area than other amendments. This implies the need to design management options to manage water, land, and irrigation farming practices that are environmentally friendly in an integrated manner to mitigate the adverse effect of sodicity on crop production in irrigated fields.

Lack of awareness and technical skills about soil sodicity amendment techniques found to be among the challenges to alleviate the problem at a wider level. Thus, existing farming practices have to be strengthened to ensure the sustainability of SSI without harnessing natural capitals such as soil, water, and others by increasing farmers' awareness and technical skills. In line with this, the role of development agents is very vital in assisting farmers to practice better environmentally-friendly farming techniques to make irrigation a sustainable livelihood system in the study area. Thus, new policy interventions are strongly recommended to empower development agents providing them with the necessary incentives to encourage them to work having frequent contact with farmers to support them depending on the needs of the farmers. In the future, it will be worth to undertake research that quantifies the effect of precipitation and evapotranspiration on soil salinity-sodicity development in different seasons of the year.

Chapter 4: Features, challenges and livelihood sustainability of smallholder irrigators

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Abstract

The study aims to investigate the effects of small scale irrigation on households' livelihood in the Central Rift Valley of Ethiopia. Data was collected through a household survey, focus group discussions, and household interviews. Small scale irrigation enhances agricultural productivity, serve as a source of diversified options to access food, creates employment opportunity, creates a means to cope up with the effects of climate variability, and increases household asset. The proliferation of new plant pests and diseases, degradation of natural resources, and biodiversity change were some of its damaging effects. The sustainable development of irrigated agriculture has continued to be unsatisfactory due to the lack of sustainability in using financial, natural resources, and technical performance of schemes. To ensure sustainable development, much work has to be done in creating access to market linkage and transportation infrastructures, access to rural financial institutions, adopting water-saving irrigation technologies, and ensure equity in water use.

Keywords: Small Scale Irrigation, Livelihood, Farmers' View, Sustainability, Central Rift Valley, Ethiopia.

4.1 Introduction

Looking at population growth projection, the Sub-Saharan Africa (SSA) region will account for about half of the global population growth between 2010 and 2050 (United Nations (UN), 2011). SSA might also face a serious challenge to feed more than 2 billion people by 2050 due to the adverse effect of climate change on rain-fed agriculture (Intergovernmental Panel on Climate Change (IPCC), 2007). Coupled to this climate change has threatened rain-fed agricultural production and increases the vulnerability of people dependent on it for their livelihood in SSA (Claessens *et al.*, 2012; Lipper *et al.*, 2014). The issue of climate change is global, long-term and it includes complex interaction between climatic, social, environmental, economic, technological, institutional, and political processes (Smit & Pilifosova, 2003).

Thus, combating climate change is a key to attain the goal of sustainable development, and achieving the goal of sustainable development is integral to lasting climate change mitigation and adaptation (Fischer *et al.*, 2007). In this regard, the contribution of irrigation towards boosting agricultural production is enormous to avert the adverse effect of climate change on rain-fed agriculture and to produce food for a rapidly growing global population. If irrigated area could be tripled by 2050, it would dramatically contribute to the food supply in SSA (Rosegrant *et al.*, 2009). The demand for irrigation water is expected to continue in SSA (Mancosu *et al.*, 2015). However, at a global level, 60% of the diverted water for agriculture does not contribute directly to food production due to inefficient irrigation systems (Food and Agricultural Organization (FAO), 2013). The same projection also showed that by 2025, 1,800 million people are expected to be living in regions with absolute water scarcity. Thus, water scarcity might be the future big challenge for expanding irrigation and to enhance sustainable agricultural production.

In Ethiopia, smallholder rain-fed dependent farmers have been facing climate-related hazards due to rainfall variability and droughts (Kassie *et al.*, 2013). In the Central Rift Valley (CRV) of Ethiopia rapid population growth, poverty, and natural resource degradation are firmly intertwined (Pascual-Ferrer *et al.*, 2014). Extreme rainfall variability has a serious impact on food security in the area due to the dependency of the population on climate-sensitive subsistence farming (Muluneh *et al.*, 2017; Yihun, 2015). Thus, the area is chronically food insecure and farmers have

been under food aid. As a result, it is incontestable that irrigation has a big role to increase rain-fed dependent farmers' resilience capacity against changing climate (Awulachew *et al.*, 2010).

The central rift valley region of Ethiopia encompasses a chain of four lakes (Ziway, Langano, Abyata, and Shala) and streams (Jansen *et al.*, 2007). Large scale national and foreign horticulture and floriculture farms have been operating in the area taking the water resources endowment as an advantage (Hengsdijk & Jansen, 2006). In the area, small scale irrigation schemes (SSIS) have been practiced on lakes, stream and river diversions, groundwater, dams, and perennial springs. There is high competition for water resources among large and small scale irrigators, commercial farmers, fishery, industrial water use, domestic water use, nature, and related eco-tourism (Jansen *et al.*, 2007; Pascual-Ferrer *et al.*, 2014). The result of this study can be used as an input for policymakers concerning small scale irrigation (SSI) development in the era of climate variability and the mechanisms required for adoption.

Previous studies conducted on analogous matters had focused on the assessment of the positive effects of SSI on rural livelihood using mainly quantitative research techniques in Ethiopia and other countries (Gebrehiwot *et al.*, 2015; Smith, 2004; Van Halsema *et al.*, 2011; Zeweld, Huylenbroeck, Hidgot, Chandrakanth, & Speelman, 2015 and others). However, in this study, a more holistic and livelihood-centered assessment of SSI agriculture was undertaken using both quantitative and qualitative data sources and deploying different analysis techniques. Thus, the objectives of the study were to (1) identify the contribution of SSI farming on rural livelihood improvement (2) investigate the damaging effects of SSI farming; (3) identify the constraints of SSI agricultural enhancement; (4) analyze the sustainability of irrigation-based rural livelihoods in the Central Rift valley regions of Ethiopia based on the perspectives of sustainable development.

4.2 Conceptual framework

The conceptual framework of the study was developed based on the framework developed by (Department for International Development (DFID), 2000) as presented in Figure 4.1. Adhering to conception by DFID (2000) "a livelihood comprises the capabilities, assets, and activities required for a means of living." The sustainability issue of livelihoods falls into two groups such as environmental and socio-economic sustainability. Environmental sustainability focuses on the internal capacity of livelihoods to withstand outside pressures. In this regard, maintaining the

natural resources endowment without affecting the benefits of the coming to the resources is taken as an indicator of sustainability by the scholars in the field. For instance, a livelihood system can be considered as not sustainable environmentally if the negative outcome of the livelihood system hinders the chances of the coming to access or claim the resources. Claims and access can be diminished in several ways, including by law, by force or by bureaucratic barriers, for example, at the local context negative effects on claims and access to resources can happen when people who are powerful hinders the access of the poor group of the community. According to Chambers & Conway (1992), in such cases, the livelihood of the power gain, however, results in total losses. On the other hand, the idea of socio-economic sustainability focuses on the human object to get benefited from the livelihood system on an equity basis and continually. The livelihoods and survival people are vulnerable to stresses like lack of food in a certain season, resource degradation, or high population growth.

Shocks that occur without prediction or suddenly occurring also negatively affect human livelihood for example, flooding or fires (Chambers, 1987). A livelihood system to be considered as sustainable should have the capacity to be resilient, resistant, or recover from stresses and shocks. According to Evans (1989), there are many livelihood stressors such as degradation of common-pool resources like water resources, deterioration of agricultural soil, reduction in rainfall, high population growth, and ecological changes that result in low economic productivity that affects the whole community. Seasonally occurring stresses are more significant in affecting the sustainability of livelihoods as they have physical, biological, and socio-economic dimensions which often interlock at bad times of the year (Chambers, 1987).

Examples of shocks affecting the whole communities include wars, persecutions and civil violence, droughts, storms, floods, fires, famine, landslips, epidemics of crop pests or animal or human illness, and the collapse of a market. As pointed out by the Commission for Sustainable Development (CSD) in 2002 as cited in UN (2018), the key objective of sustainable development relies on alleviating poverty, adopting sustainable ways of consumption and production aspects, and managing natural resources to ensure economic and social development.

Sustainability of irrigation-based livelihoods might be affected by multiple factors as shown in Figure 4.1. On the other hand, SSI development is affected by different interrelated factors such

as access to market and transportation services, which largely determines the farmers’ economic gain from SSI (Amede, 2015). The type of available irrigation technology also determines the development of SSI because some technologies are friendly for smallholder farmers while others might not be conducive for the farming community in a specific area. Farmers’ level of access to the five livelihood capitals (human, social, physical, natural, and financial) affects the sustainability of development interventions in a given area, in this context SSI development (DFID, 2000). Government policies on agriculture, SSI, and sustainable development also have a detrimental effect on the enhancement of irrigation-based livelihoods (Ministry of Water Resources (MoWR), 2002).

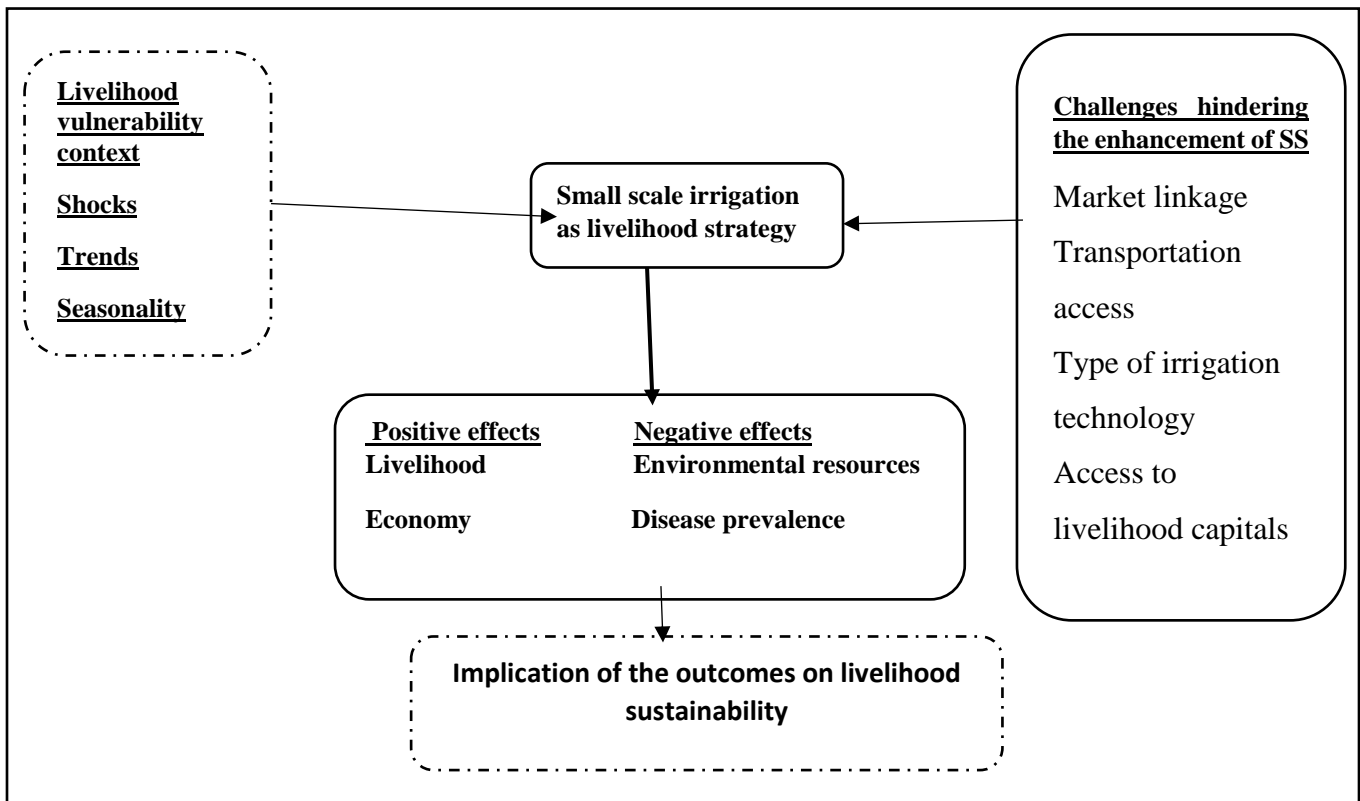


Figure 4.1: Conceptual framework (source: Authors own construction)

This study analyzed the livelihood contribution of SSI from different dimensions. It also made an investigation on the unintended damaging effects of SSI concerning socio-economic and environmental resources aspects. Furthermore, the sustainability of irrigation-based livelihood is the key concept to validate the significance of SSI for sustainable development in the study sites.

A livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term (Chambers & Conway, 1992).

4.3 Methods of data analysis

The survey data were analyzed using descriptive statistics. The quantitative data that is collected using a household survey questionnaire were analyzed using descriptive statistics. Community based wealth indicators were used to analyze the contribution of irrigation comparing with non-irrigation users following Duguma (2015). The qualitative data were organized and reduced into themes, interpreted, and presented concurrently with the quantitative data. The data was analyzed using with and without irrigation and before and after irrigation techniques to investigate the livelihood effects of SSI agriculture, the constraints in the development SSI, and the sustainability of irrigation-based livelihoods.

4.4 Results and discussion

4.4.1 Features of selected irrigation schemes

Farmers reported that using pressurized irrigation system provides better source of water than gravity. Based on FGDs held with farmers at Arata Chufa and Shelad the use of pond for night time water storage reduce the problem of scarcity of irrigation water to some extent. SSIS that are found in ATJK district have better access to market and irrigation water compared to Zeway Dugda based on the discussion held with farmers. Smallholder irrigated farming characterized by having both positive and negative effects on the livelihood of the farming households.

Table 4.1: Summary of selected SSIS

District	Name of SSIS	Number of beneficiary HHs		Irrigated area (ha)	Year of establishment	Source of water	Type of irrigation
		MHH Hs	FHHHs				
Zeway Dugda	Arata Chufa	279	45	100	1995	Chufa River, Pond	Gravity
	Sheld	223	54	75	1977	Katar River, Pond	Gravity
ATJK	Dodicha	235	45	147	1997	Bulbula River	Pressurized
	Bochessa	209	113	116	2005	Bulbula River and Groundwater	Pressurized
	Gulba Aluto	185	93	102	2007	Bulbula River	Pressurized

Source: Zeway Dugda and ATJK districts Irrigation Office, 2017.

The views of irrigation user farmers on the effects of SSI on livelihood was analyzed and presented in Figure 4.2. The survey result showed that some farmers viewed only positive effects, some only negative effects and others both types of effects. Relatively larger number of respondents in Zeway Dugda viewed negative effects of SSI agriculture compared to ATJK. This is due to farmers' limited access to market and water scarcity problems in Zeway Dugda district. Irrigation users in FGDs at Arata Chufa confirmed the frequent problem of crop failure due to water scarcity during dry season in particular. On the other hand, in the good cropping seasons when farmers get better production they gain low income from selling their irrigated products because they sell their produce with low price in the farm gates. Smith (2004) and Brabben, Angood, Skutsch, and Smith (2004) argued that negative effects of irrigation outweighs its positive livelihood effects due to its disproportionate role in increasing the wealth of the already wealthy group. Irrigation has both benefits and negative effects with respect to societal equity, environment and health (Namara *et al.*, 2010). Van Den Berg and Ruben (2006) argued that irrigation played positive role in the development of Ethiopia.

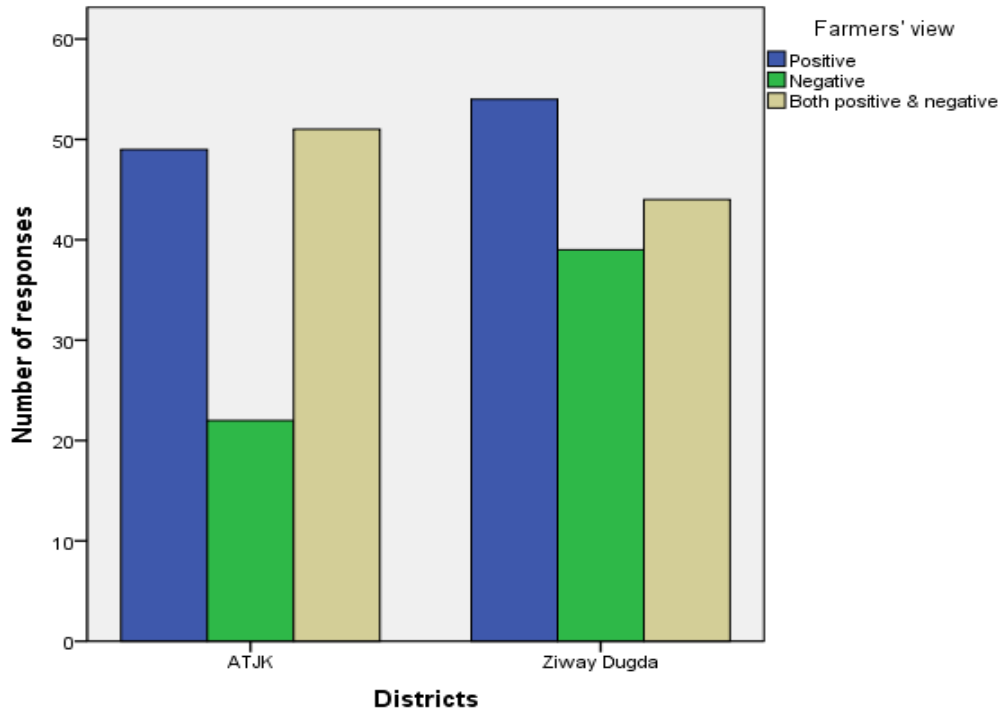


Figure 4.2: Irrigators’ view on the effects of SSI on livelihood

4.4.2 Livelihood contributions of smallholder irrigation: Users’ view

The major positive outcomes of SSI were presented and discussed in this section (Table 4.2).

Asset creation and household economy

In the view of the majority of the farmers (75%), SSI helped farmers to build their HH assets. Compared to Zeway Dugda district relatively larger percentage of respondents in ATJK district noticed that households were able to purchase different household goods (television, sofa, motorcycle, and the like) since they have begun SSI (Table 4.2). Furthermore, 62.2% of the respondents indicated that SSI contributes to increasing household income. “Those farmers who have no livestock bought cattle and goats. Some farmers bought a motorcycle from income generated by irrigation” (FGD, Irrigation users, Bochessa Kebele). The findings of Getnet *et al.* (2017) indicated the role of irrigation to support the livestock sector on sustainable basis through providing opportunities for farmers to grow irrigation-based fodder. The interviewed farmers also confirmed the economic benefit of SSI as noted in the following quote:

My income is increasing because of irrigation and hence I have changed my house from grass-roofed into a corrugated iron sheet, bought new oxen and household furniture. The

income obtained from irrigation helped me to cope up in times of shocks (Male head interview, 46 years old, Gulba Aluto Kebele).

Table 4.2: Contribution of SSI agriculture towards improving rural livelihood: Users' view.

Livelihood contribution of SSI	ATJK		Zeway Dugda		Total	
	Freq.	%	Freq.	%	Freq.	%
Better food availability during dry spells for HH consumption	89	73	72	59	161	62.2
Improvement in agricultural production	101	82.8	114	83.2	215	83
Increase HH income	86	70.5	75	54.8	161	62.2
Contribute to livelihood diversification	45	36.9	56	45.9	101	39
Resist/coping drought situation	99	81.2	108	78.8	207	79.9
Purchase livestock (Oxen, cows, goats and others)	50	41	59	43.1	109	42.1
Purchase household assets (Sofa, Television, motor cycle)	105	86.1	89	65	194	75
Build houses in urban areas	78	63.9	58	42.3	136	52.5
Construct houses with corrugated iron sheet roofs	111	91	116	84.7	227	87.6
Use credit and pay back credit	35	28.7	24	17.5	59	22.8
Enable saving money at saving institutions	74	60.7	31	22.6	105	40.5
Cover educational costs of children properly	89	73	62	45.3	151	58.3
Create employment opportunity	108	88.5	95	69.3	203	78.4
Increase agricultural labour wage	95	77.9	80	58.4	175	67.6

Source: Survey data, 2017

Tandem with the views' of the research participants, several authors had long ago noted that irrigation helps farmers to generate regular income (Tadesse, Berhane, & Bheemalingeswara, 2008). Moyo, Van Rooyen, Moyo, Chivenge, and Bjornlund (2017) reported that SSI negatively affects farm income. The level of access to natural capital is one of the key factors determine welfare gains from irrigation (Tekana & Oladede, 2011).

As can be seen from Table 4.2, in the view of a relatively small proportion of respondents (22.8% and 40.5%) irrigation user farmers have been practicing credit service and saving money respectively. In the FGDs farmers mentioned the inaccessibility of banks and micro-finance for the limited practice of saving. Farmers noted that they have less practice to use credit because they fear how to pay back their credit as they have no guarantee of getting good production from irrigation farming due to the irregular nature of agricultural income. Thus, farmers' demand for financial services is unmet and consequently affects their potential to invest in SSI. The demand

for financial services was unmet among farmers in Africa (Alliance for a Green Revolution in Africa (AGRA), 2017). Lefore *et al.* (2019) reported that rural financial institutions are unreachable for the rural people as they concentrate in regional and district towns. Saving has a critical role in financial sustainability as agricultural income has irregularities (AGRA, 2017). This implies that agricultural development plans and policies have to give a strong emphasis on sustainable building irrigators' financial capacity.

Improvement in agricultural production

The study indicated that in the view of the majority of the farmers (83%) SSI played a role in enhancing agricultural production. The FGD participants indicated that rain-fed farming doesn't even support them to produce an adequate amount of production for their HHs food consumption due to rainfall variability. In the view of irrigators, SSI allows us to produce a better amount of production per plot of farmland compared to rain-fed farming. SSI also helped farmers to produce high-value market-oriented agricultural products. In our field visit, we have observed the practice of intercropping in irrigated plots at Shelad (Figure 4.3) and Arata Chufa; farmers intercrop Banana, Cabbage, Papaya, Coffee, seedling development and the like. Intercropping is advantageous as it ensures optimum use of the soil, serves as insurance against crop damage in areas that were vulnerable to extreme weather fluctuation, and brings greater financial return.



Figure 4.3: Irrigated farm land at Shelad with intercropping practice (Source: own picture 2017).

The knowledge in the works of analogous literature also backs up similar views that irrigation increases agricultural production efficiencies (Jara-Rojas, Bravo-Ureta, & Díaz, 2012). Irrigation support farmers to cultivate highly valued crops (Tadesse *et al.*, 2008). Moyo *et al.* (2017) indicated different findings, SSI results in low yields due to poor soil fertility, limited agricultural knowledge, and other factors. Although SSI has a big role in improving agricultural productivity in the study sites, appropriate soil and water conservation practices should be implemented to optimize its benefit.

Livelihood diversification

In this study, in the view of a relatively large proportion of respondents in Zeway Dugda (45.9%) compared to ATJK (36.9%), SSI has played the role of livelihood diversification (Table 4.2). Based on discussions made with FGDs participants, farmers explained two different types of scenarios in this aspect. In one aspect, SSI creates financial potential, for example, farmers either purchase or construct houses in urban areas. In such a way, farmers get additional income by renting houses in urban areas, open shops, or get income from available employment opportunities

in urban areas. On the other hand, SSI also creates the opportunity for farmers in the rural areas itself to diversify their livelihood system to trading activities like animal fattening to sell the livestock in time of financial need, planting, and selling seedlings of onion, cabbage and like for other irrigators. The interviewed farmers emphasized that farmers can practice livelihood diversification system if they can get better income from SSI during good market prices for some consecutive cropping seasons. Otherwise, the life of the irrigators remains to be hand-to-mouth. In the second scenario, the study participants discussed that irrigation user farmers forced to diversify their livelihood systems like livestock fattening, trading activities, working as employees in different organizations in nearby urban areas and the like when they lack the hope to get sustainable benefit from irrigation farming due to water scarcity, limited market access and financial inability to invest in SSI. In such circumstances, some farmers choose to work in trading activities while other farmers lease out their irrigable farmland and work being hired commonly as a guard in nearby offices in their locality or work as a daily laborer. Moreover, some farmers who have good access to Lake Zeway engaged in a fishery in ATJK; some farmers practice fish farming in an artificial pond near to their irrigated plot while they are working on irrigation at the same time in Zeway Dugda as shown in Figure 4.4.



Figure 4.4: Artificial pond for fish farming near to a farmer's irrigated farm land (Source: Own picture, 2017)

Ellis (2000) noted that policies should facilitate the adoption of multiple livelihood strategies because diversified livelihoods are less vulnerable than undiversified (Ellis, 2000). Therefore,

farmers have to be encouraged by providing appropriate pieces of training on viable alternative livelihood strategies in addition to SSI to cope up with the effect of climate variability on agriculture and to ensure sustainable development in the face of climate change.

Food availability for household consumption and coping with drought

In this study, based on the view of 80% of the respondents SSI enables farmers to create a capacity to cope up with the risks of recurrent drought. Furthermore, in the view of 62.2% of the farmers SSI plays a role in helping farmers to produce food for their HH consumption including diversities of cereals, vegetables, and fruits (Table 4.2). For example, cabbage was mentioned by farmers as food for themselves and feed for their livestock during dry spells due to its short growing season. “It is the irrigation farming that helps to sustain our life with the help of God in the severe drought situation last year (⁹)” (Irrigators FGD, Shelad SSIS). Farmers also noted that SSI being a coping mechanism against climate variability while the fate of rain-fed dependent farmers is either to work as a daily laborer or destocking their livestock. The FGD participants pointed out that irrigators used to sell their irrigated vegetables and buy staple food items like maize and Teff when there is a crop failure in rain-fed agriculture. Irrigation is useful for risk reduction, food security, and poverty reduction (Jara-Rojas *et al.*, 2012). In Ethiopia, irrigation reduces the number of people dependent on food-for-work programs (Van Den Berg and Ruben, 2006). Smallholder irrigation improves HHs feeding habits and food security (Domenech, 2013; Tadesse *et al.*, 2008). Yet, Moyo *et al.*, (2017) reported that SSI resulted in food insecurity in Zimbabwe. In Bangladesh SSI farming increased food production, however, HHs lack a balanced diet due to rice monocropping (Brabben *et al.*, 2004).

Employment opportunities and wage improvement

The study revealed that in the view 78.4% and 76.6% of the participants SSI farming has contributed to creating new employment opportunities and increasing agricultural labor wage respectively (Table 4.2). In the FGDs farmers pointed out that the non-irrigators, women, poor farmers, and landless are the beneficiaries of the employment opportunities. The daily wage rate has increased as the demand for agricultural labor increases. SSI also increased the migration of

⁹ It refers to the year 2015/2016 when there was a severe drought in the area

people into the area from other parts of the country such as Amhara, Tigray, and the like either to invest in irrigation or search for a job. The interview conducted with a 38 years old male farmer at Shelad Kebele confirmed the labor migration into the irrigated fields.

I came to the Shelad area some 15 years back from Wollo¹⁰ to work as a daily laborer as I heard about the available employment opportunities in irrigation farming from my friends. I was working as a daily laborer for about 7 years in irrigation farming. Once I saved money to invest in irrigation agriculture, I began to work on it by renting irrigable land from other farmers. I find irrigation agriculture to be profitable for me.

More specifically, SSI expansion in the area created opportunity for women to generate income working as a daily laborer. Based on the interview we had with farmers, FHHs most of the time work as a daily laborer for other farmers and investors in their area. For instance, Theis et al. (2018) argued that irrigation intervention can add more labor burden on women without improving their right to control income as there is conflate use and Fructus rights in relation to the “elite capture” concept in the household. Yet, according to Van Koppen *et al.* (2013), if women mobilize inputs themselves and are included in irrigation institutions, they are more likely to benefit from irrigation interventions. On the other hand, SSI has certain undesired outcomes from the attraction of employment in the locality such as population pressure, expansion of settlements, and pressure on the natural resources. Hence, managing these undesired outcomes is valuable to enhance the sustainability of irrigation-based livelihoods. Irrigated areas are more labor-intensive than rain-fed areas, which increases labor demand having a positive effect on the wage of agricultural laborers (Brabben *et al.*, 2004; Domenech, 2013). This implies the spillover and indirect benefits of SSI.

Improvement in children’s education

In the view of irrigators, SSI helped farmers to cover their children’s educational expenses (Table 4.2). Farmers noted that although irrigators most of the time use family labor for agricultural activities including their children, the improvement of their income from SSI helped them to use hired labor. Hence, they can send all their children into school even into urban schools. “My income and livelihood are changing since I have started working in irrigation agriculture. I am

¹⁰ It is found in the northern part of Ethiopia, which is more than 600km from the Shelad area.

teaching my children from the income generated from irrigation agriculture” (Interview with Female household head, 36 years old, Arata Chufa). Chazovachii (2012) reported that income generated from SSI supported farmers to send their children to school. The introduction of irrigation has increased students’ enrollment, girls’ school attendance, and women's education (Brabben *et al.*, 2004).

4.4.3 SSI Agriculture and Wealth Creation: Comparing Irrigation Users and Non-users

Based on community wealth indicators, farmers are considered as wealthy if they have houses made of corrugated iron sheet, build houses in urban areas, educate their children in urban areas, using hired labor for farming, saving money at banks and microfinance, able to feed his/her family throughout the year and having much livestock. These indicators were used to compare the wealth status of the irrigation user and non-users (Table 4.3).

In this study irrigation user HHs found to have better wealth status than non-users in all community wealth indicators. The difference is statistically significant at $P < 0.01$ for all indicators except saving money at banks $P < 0.05$. Compared to non-irrigators, irrigators were able to construct better housing condition made from cemented wall, cemented floor, corrugated iron sheet roof and own houses in urban areas. Moreover, the use of hired labour force is significantly higher for irrigation users (Table 4.3). Yet, this is not always true because some poor farmers even lease out their irrigable land for others and work as a daily labourer. This implies that irrigation is not pro-poor in the study sites. If there is inequality in the access to livelihood assets, irrigation may result in increasing relative poverty (Smith, 2004).

Although investing in SSI helped irrigators to provide food for their HH members throughout the year in some chronic drought years, both irrigators and non-irrigators were under food aid support, for example, during the 2015/16 severe and prolonged drought in the area. Irrigation users were asked why they were under food aid like the non-irrigators during that drought year. Small irrigable land holding, water scarcity (rivers dried during drought season) and poor market linkage were mentioned by irrigation users as factors that hinder their potential to provide adequate food for their HH members.

Table 4.3: Role of irrigation on HHs' wealth creation based on community's wealth indicators

Variable Definition		Irrigation user		Irrigation non-user		Total		Chi-square value
		Freq.	%	Freq.	%	Freq.	%	
Housing condition	Corrugated iron sheet	77	29	24	14	101	23.4	72.31***
	Grass roofed	79	31	124	72	203	47.1	
	Both types	103	40	24	14	127	29.5	
	Total	259	100	172	100	431	100	
Housing location	Rural	138	53.3	152	88.4	290	67.3	60.24***
	Urban	24	9.5	0	0	24	5.6	
	Both rural & urban	97	37.5	20	11.6	117	27.2	
	Total	259	100	172	100	431	100	
Location of children education	Rural	83	39	68	59	151	46	13.85**
	Urban	49	23	12	10	61	18.5	
	Both rural & urban	81	38	36	31	117	35.5	
	Total	213	100	116	100	329	100	
Hire labour	Always	79	30.5	12	7	91	21.1	54.57***
	Sometimes	51	19.7	15	8.7	66	15.3	
	Rarely	30	11.6	33	19.2	63	14.6	
	Never	99	38.2	112	65.1	211	49	
	Total	259	100	172	100	431	100	
Food provision for HHs throughout the year	Always	68	26.3	11	6.4	79	18.3	60.91***
	Sometimes	61	23.6	15	8.7	76	17.6	
	Rarely	52	20.1	38	22.1	90	20.9	
	Never	78	30.1	108	63	186	43.2	
	Total	259	100	172	100	431	100	
		Always	31	12	4	2.3	35	
	Sometimes	36	14	14	8.1	50	11.6	
Saving money	Rarely	73	28.2	39	22.7	112	26	24.33**
	Never	119	46	115	67	234	54.3	
	Total	259	100	172	100	431	100	

*** and ** significance at P-values 0.01 and 0.05 respectively

Source: Survey data, 2017

For example, the poor market linkage hindered irrigators not to sell their irrigated vegetables with good price and to purchase stable food items. In addition, SSI helps irrigators to have more livestock. The farmers participated in the FGDs noted that livestock have better resistant to immediate climate variability than crop production. SSI found to be beneficial towards improving the livelihood of the farming community, however, it is not pro-poor and is not a lasting solution during extended drought situation. Therefore, policies and strategies have to be designed in the

provision of agricultural inputs in affordable prices for farmers, rural financial institutions have to be reachable for the farming community, drought tolerant crops have to be introduced and much work has to be done by development agents in helping farmers to diversify their livelihood strategies.

4.4.4 Negative effects of small scale irrigation

Prevalence of plant disease, pests, and new weeds

The study revealed that in the view of 95.4% and 86.5% of the respondents there is the prevalence of plant disease and pests and growth of new weeds respectively due to SSI (Table 4.4). For example, Tomato, Cabbage, Potato, and Onion are commonly infected with diseases. The FGD participants also stressed that some of the vegetable diseases are resistant to pesticides. “The disease of tomato is very dangerous. We bought a pesticide with 3000 Birr, but it doesn’t kill the worms. In the past, we didn’t know any vegetable disease and we have been getting a good harvest” (Irrigators FGD, Arata Chufa). The interviewed farmers in Bochessa reported the growth of two previously unknown weeds in the irrigated land. The farmers reflected that the high financial demand of SSI farming for controlling pests and weeds discourages them to continue investing in irrigation. This implies that appropriate pest and weed management are among the prioritized aspects to sustain the benefit of SSI. Thus, integrated pest management should be taken as an intervention to resolve the problem. Ayele *et al.* (2013) and Asayehegn (2012) have similar findings.

Degradation of land and water resources

Compared to the land productivity before the expansion of SSI in the area, its productivity has been declining due to the expansion of intensive irrigation farming based on the view of 88.8% of the respondents as shown in Table 4.4. The coming of urbanites to invest in irrigation agriculture renting land from poor farmers was mentioned as a factor for the deterioration of farmland by farmers in the FGDs. Farmers noted that the application of a high amount of fertilizer and pesticide by urbanites are factors that aggravate the deterioration of farmland, for example in Bochessa and Gulba Aluto Kebeles many urbanities rent irrigable land and invest in irrigation agriculture. Besides, salinity development on farmland was among the serious problems that constrain the

growth of vegetables as shown in Figure 8. Farmers reported that many farm plots become no more productive due to the effect of salinity particularly in Bochessa groundwater irrigated plots. On the other hand, water logging is a serious problem that makes some hectare of land out of production in Shelad SSIS. Consequently, some farmers have the intention to stop working on SSI and change their livelihood into livestock husbandry and other non-farm activities.

Table 4.4: Negative effects of SSI based on irrigation users' view

Negative effects of SSI	ATJK		Zeway Dugda		Total	
	Fre.	%	Fre.	%	Fre.	%
Growth of new weeds	109	89.3	115	83.9	224	86.5
Prevalence of crop disease and pests	118	96.7	129	94.2	247	95.4
Prevalence of animal disease	32	26.2	41	30	73	28.2
Prevalence of human disease and harms to human	14	11.5	21	17.2	51	19.7
Land fertility declines	97	79.5	79	57.7	230	88.8
Degradation of water resources	104	85.3	113	82.5	217	83.8
Water logging due to seepage	23	18.9	84	61.3	107	41.3
Increased soil salinity	46	37.7	54	39.4	100	38.6
Introduction of exotic species of plant	34	28	45	33	79	30.5
Drive out indigenous species of plant	82	32	63	46	145	56
Reduction of the local biodiversity	30	24.6	38	27.7	68	26.3

Sources: Survey data, 2017

Etissa *et al.* (2014), supports our result. The poor performance of irrigation institutions restrict the resource-poor farmers' access to natural resources and it might lead to serious environmental degradation (Lafore *et al.*, 2019). The study also revealed that in the view of 83.8% of the respondents SSI causes the reduction of both volume and quality of water resources (Table 4.4). "It is because of the expansion of irrigation agriculture that the river now becomes empty of water (Interview, 37 years old, MHHH, Arata Chufa)." Fertilizer and pesticide use causes the deterioration of Lake Ziway¹¹ (Teklu *et al.*, 2018).

¹¹ Main water source for irrigators at ATJK, the rivers originate from this lake



Figure 4.5: Farm lands affected with salinity due to irrigation at Bochessa (left) and Shelad (right)
(Source: own picture 2017)

According to Getnet *et al.* (2014), increased evapotranspiration consumed 207 Mm³ yr⁻¹ more water (1990-2007) of lakes and land surfaces in CRV. These authors also reported the trend of increasing irrigation water abstraction from ± 20 to 285 Mm³ yr⁻¹. The dominant field water application system is furrow irrigation (Figure 3.6), which is less efficient compared to sprinkler and drip irrigation. The irrigation water applied in farm fields didn't much to crop water needs and poor irrigation water management results in misuse of water (Derib *et al.*, 2011; Etissa *et al.*, 2014). On the other hand, efficient agricultural water management at the farm level is key for the future sustainability of agricultural water both globally and locally (Jara-Rojas *et al.*, 2012).

Based on our field visit and discussion with farmers, loss of irrigation water due to leakage of earthen canal, ponds filled with sediments, broken Polyvinyl chloride (PVC), growth of plants along earthen canals and canals filled with soil and other materials are common problems in the areas as shown in Figure 4.7. The types of irrigation scheme, crop choice and the irrigation methods have significant effect on water use efficiency (Speelman *et al.*, 2008). According to Sakaki and Koga (2013), sustainability of irrigation schemes can be achieved with the fulfillment of water utilization system, operation and maintenance system and succession system.



Figure 4.6: Furrow irrigation field water application system (Source: own picture 2017)

Accordingly to Derib *et al.* (2011), the use of costly pumped irrigation to use deficient irrigation and Comas *et al.* (2012) suggested the use of crops that need less water and empowering farmers to maintain canals and use proper irrigation schedules. On the other hand, Assefa *et al.* (2016) recommends the use of deficient supplemental irrigation in areas where there is scarcity of irrigation water using rain water harvesting techniques. These all has implications on the urgency to adopt water-saving irrigation technologies as a pressing issue to sustain irrigation-based livelihoods. Thus, to ensure sustainable irrigated agriculture efforts are important towards optimizing the productive potential of the sustainable management of two important natural resources-land and water. Non-sustainable irrigation systems are the constraints that compromise the benefits of smallholder farmers from SSI. According to some previous researchers (Amede, 2015), many schemes do not operate at full capacity due to design failures, excessive siltation, poor agronomic and water management practices, and weak local institutions.



Figure 4.7: Irrigation water conveyance systems damaged canals (left) broken PVC (middle) and pond filled with sediments (right) (Source: own picture 2017).

Livestock and human diseases

Small scale irrigation expansion results in the prevalence of livestock and human diseases based on the view 28.2% and 19.7% of respondents respectively (Table 3.4). The respondents reported that sometimes livestock gets sick while they eat weeds from irrigated fields and drink irrigation water. FGD participants in Arata Chufa reported the death of three people entering into the irrigation water pond as it has no fence. Moreover, fever, typhoid, typhus, common cold, and aching were some of the perceived human health problems due to the expansion of SSIS. The respondents noted that giardia is the frequently occurring human health problem because people simply drink the irrigation water. The use of unregulated pesticide use and unsafe handling practices are aggravating human poisoning by pesticides in developing countries (Domenech, 2013). Asayehegn (2012) indicated that 25% of adult and child diseases are caused by malaria due to swampy areas around irrigation dams. The author also pointed out the prevalence of fungal, bacterial, and viral diseases due to the expansion of SSI.

The concentration of some physicochemical parameters in Lake Ziway is above the maximum permissible limit of the standard for drinking water in Ethiopia (Teklu *et al.*, 2018). This has a big implication on the adverse effects on human health particularly on the rural people, who are still drinking the Lake water. Yet, the residents of Ziway town are not using Lake water for drinking purposes currently. According to Domenech (2013), irrigation might affect human health both positively (improved nutrition and hygiene) and negatively (production of contaminated crops due to pesticides and increasing water-borne diseases). Farm HHs with poor health might not use productivity-enhancing and resource-conserving technologies that affect the sustainability of agriculture (Ersado, 2005). Health impacts with the expansion of irrigation schemes in CRV might be a future big challenge, however, it needs further clinical research. Generally, precautions measures are important to avoid health problems while planning irrigation schemes. Moreover, irrigation water quality monitoring has to be done.

Modification of the local biodiversity

The benefits of irrigation are offset by environmental costs on wetlands and aquatic animals (Lemly, Kingsford, & Thompson, 2000). The survey data revealed that in the view of 56% of the respondents the expansion of SSI farming results in driving out indigenous species of plant. Based on the view of 30.5% and 26.3% of the respondents SSI agriculture causes the coming of exotic species of plant and reduction of the local biodiversity respectively (Table 3.4). For instance, farmers in Arata Chufa noted that they were planting orange, guava, and coffee in the past but now they don't plant these plants. In Shelad site also the interviewed farmers stated that they were planting orange, lemon, and mango in the past, currently these fruits don't grow in the area. Irrigators in Shelad relate the current disappearance of many wild animals from the area with the expansion of agriculture in general including SSI. Farmers in Dodicha *Kebele* relate the disappearance of bees from their area with coming and expansion of irrigation. Moreover, the reduction in the quality and quantity of fish stock at Lake Ziway was indicated by the interviewed farmers in Bochessa *Kebele* with the expansion of large and SSI. Biodiversity is so complex and its modification might be affected by many observable and unobservable factors including climate change and other factors. Thus, future researches are recommended on the effect of SSI on biodiversity based on species-level of analysis, investigating the historical aspects of species in the area and how it affects the livelihood of the community due to the interaction between SSI and

biodiversity. Generally, unless these negative effects of SSI are addressed, it is difficult to get the benefits of SSI as it is planned. Therefore, tackling these undesired effects of SSI should be prioritized in the SSI development plans and strategies. Warble

4.4.5 Challenges of small scale irrigation

Market Saturation

Agricultural engineers assumed that economic development is granted once farmers are provided with irrigation equipment. However, this can be practical when irrigation potential positively articulates with market demands (Van Der Zaag (2010). In this study according to the view 80.7% of the respondents sometimes the local market gets saturated with homogeneous and perishable vegetables like tomato, onion, and cabbage. In such situations, farmers just leave their vegetables in their farm plots for livestock feed if they consider that the market price even does not cover transportation fees. Van Der Zaag (2010) noted that highly volatile and unpredictable market situation in his words “merciless market gluts” have been disappointing innovative farmers in Africa. Limited market access for irrigated crop results in price slumps due to lack of marketing facilities (Amede, 2015; Ayele *et al.*, 2013). To overcome the problem, planting dates and diversification of commodities and market linkages should be considered. Mobile technologies are important for better dissemination of market information to get profit from irrigated production (Moyo *et al.*, 2017).

Table 4.5: Challenges hindering SSI enhancement

Challenges of SSI agriculture	ATJK		Zeway Dugda		Total	
	Fre.	%	Fre.	%	Fre.	%
Market saturation	118	96.7	91	66.4	209	80.7
Irregular financial returns	107	87.7	116	84.7	223	86.1
Conflicts on water use rights	65	53.3	102	74.5	167	64.5

Sources: Survey data, 2017

Irregular financial returns from small scale irrigation

In the view of the highest percentage of the respondents (86.1%), irregular financial returns from SSI farming is the other challenge of irrigators (Table 4.5). The market price of the vegetables is highly fluctuating from one cropping season to the other. The respondents also noted that

agricultural input prices have been increasing in the area. Irrespective of this irrigated vegetables found to be unprofitable particularly when there is no good market price. According to the view of irrigators, the benefits of irrigation can be optimized if agricultural markets are managed by farmers' cooperatives without middlemen intervention. Farmers' limited access for output markets, selling outputs in the farm gates without price information in urban centers, and poor institutional setup makes irrigation unprofitable (Mwamakamba *et al.*, 2017). Farmers have limited access to input markets and markets are uncoordinated (Moyo *et al.*, 2017). To manage this, Amede (2015) suggested the involvement of agribusinesses and processes that could facilitate the value chain and reduce farm losses.

Water use right related conflicts

In the current study, a larger proportion of irrigators perceived conflict over irrigation water use right as shown in Table 5.5. Conflict on irrigation water found to be a serious problem in Zeway Dugda compared to ATJK because ATJK has access to lakes and groundwater. FGD participants in Arata Chufa Kebele reported the existence of fighting among upstream and downstream farmers almost on daily basis due to competition for irrigation water; some farmers even fight among each other with *Konchera*¹². Water scarcity and inappropriate utilization is a major challenge of irrigators in Tigray, Ethiopia (Tadesse *et al.*, 2008). Interviews also confirm the survey data.

I have been waiting for watering my onion as per the schedule. One farmer in the upper of my plot diverts my water. I warn him not to divert it. He ignores my warning and used to water his plot. Then, I fought with him seriously (Household interview, 32 years old, MHHH, Arata Chufa).

The study also revealed that malfunctioning water distribution systems resulted in inequitable water use and conflicts. The interviewed farmers confirmed the situation; “let’s talk in the name of God, there is no equality between women and men in participating at SSI and the Kebele didn’t follow up our irrigation schemes properly” (Household interview, 45 years old, FH HH, Arata Chufa). Moreover, the interview with a 63 years old MHHH irrigator in Shelad SSIS can be also a good account.

Old men like me cannot water their field competing with young people. The young can compete and water their farmland. We old men simply abandon and go without watering our land in fear of the harsh conflict over irrigation water.

¹²

Unfair distribution of water is a big constraint for irrigators (Ulsido and Alemu, 2014). In Africa elderly, women, and poor farmers are not beneficiaries of SSI (Lefore *et al.*, 2019). When people start to irrigate, they hurt other users in the watershed. Thus, some form of coordination and rules governing water use can help to prevent conflicts and give users some assurance that their investments in irrigation will be sustainable and to attain the goal of sustainable development (Meinzen-Dick, 2014).

Gender Inequality

In this study, in all investigated SSIS, the number of MHHs is higher than FHHs in WUAs and the majority of the committee members are men while there are few numbers of women being a member WUAs committee particularly women take the responsibility to be casher for the committee. The results of the household interview revealed that the benefits of SSI such as resilience, income, food security are not equally shared among household members in all investigated SSIS. In most cases, the benefits reach to women through their husbands. Yami (2013) reported that all WUAs committee members are men and there are no women being members of the WUAs committee. Participatory approaches are important to facilitate greater efficiency and effectiveness of development interventions and enable democratic decision-making processes (Hickey & Mohan, 2005; Imburgia, 2019). World Bank (2009) indicated that due to the gender stereotype women are primarily considered as housewives and mothers while men are considered as farmers and irrigators and as result policies and programs most of the time overlook the knowledge, tasks, needs, and requirements of women in agricultural water management. Parker et al. (2016) also reported that women faced challenges to rent land, rent or purchase farming equipment, and purchase agricultural inputs mainly due to having limited access to secure finance as men have the right to control the household finance. McCornick et al. (2003) stated that gender issue should be given consideration at field level (to ensure gender equality in water and land right and related obligations), water user association level (to avoid gender-based exclusion from participation) and leadership level (to ensure equal opportunities for leadership position). Parker et al. (2016) also noted that irrigation provides a medium-term buffer in response to seasonal and drought-induced food insecurity for rural poor households. Nevertheless, women's benefit in this aspect depends on their access to other resources and

opportunities like economic means to invest in land, labor, equipment, and inputs and participation in decision making to secure water rights.

In most cases women found being deprived of secured land tenure rights, which consequently hinder women's access to agriculture water resources, to control other productive resources and opportunities (Jong et al., 2013; Parker et al., 2016; World Bank, 2009). This is the big challenge that creates the gender gap which deters the poverty-reducing potential of SSI in many developing countries (Meinzen-Dick, 2014). According to Sadoff et al. (2015), women farmers are often marginalized and particularly vulnerable to current and future climate variability and water insecurity. Improved water security is central to improving people's resilience to climate variability and extreme weather events (IFAD, 2007).

The study indicated that there is gender inequality in the participation of SSI, taking a position as a committee member in WUAs, and getting benefited from SSI although women contributed most of the labor and tedious activities in the irrigation farming. Women found to be disadvantaged to get benefit from their participation in irrigation. To enhance the benefit of women in their participation in SSI, a broad conceptualization of rights and access to productive resources is needed that is sustainable, gender-responsive, and inclusive. This approach has to be consistent with national human rights standards and the human rights-based approach to development. Generally, the limited participation of women in the WUAs committee has the potential to compromise the benefits that women can get from SSI. Thus, the attitude of women and men should be changed towards equal participation in irrigation, sharing benefit, and decision making power so as to enhance sustainable agriculture, which is highly gender-sensitive.

4.4.6 Small scale irrigation and livelihood sustainability

The sustainability of irrigation-based livelihoods in ATJK and Zeway Dugda districts appearance gloomy based on the data at hand in the perspective of sustainable development. Land and water resources being the crucial natural resources in irrigation have been under a stressful situation, which consequently compromised farmers' economic gain from SSI on a sustainable basis. Thus, conserving land and water resources should be prioritized by introducing organic fertilizer, water-

saving irrigation technologies (drip and sprinklers through government subsidies), and irrigation water payment systems to attain the goal of sustainable development in agricultural-based livelihood systems. Inefficient irrigation water utilization and degradation of water resources have been threatening the sustainability of livelihoods dependent on water-based agricultural development. The Ethiopian government should ensure equitable surface water access and, in situations when it is necessary, expand sources of surface water during irrigation seasons by employing appropriate planning and basin-wide management (Awulachew, 2019). The same author also indicated that to ensure sustainable development addressing the critical challenge of land degradation is the priority, therefore, watershed and environmental management must be integrated into all irrigation development projects with particular attention in low land areas that are prone to salinization and poor soil quality. According to Sakaki and Koga (2013), the sustainability of irrigation schemes can be achieved with the fulfillment of water utilization system, operation and maintenance system, and succession system. As indicated in Figure 3.8 the interrelated aspects of socio-economic and environmental interfaces, whenever one system is not well functioning, the others will be also disturbed, which consequently undermines the sustainable development of the area.

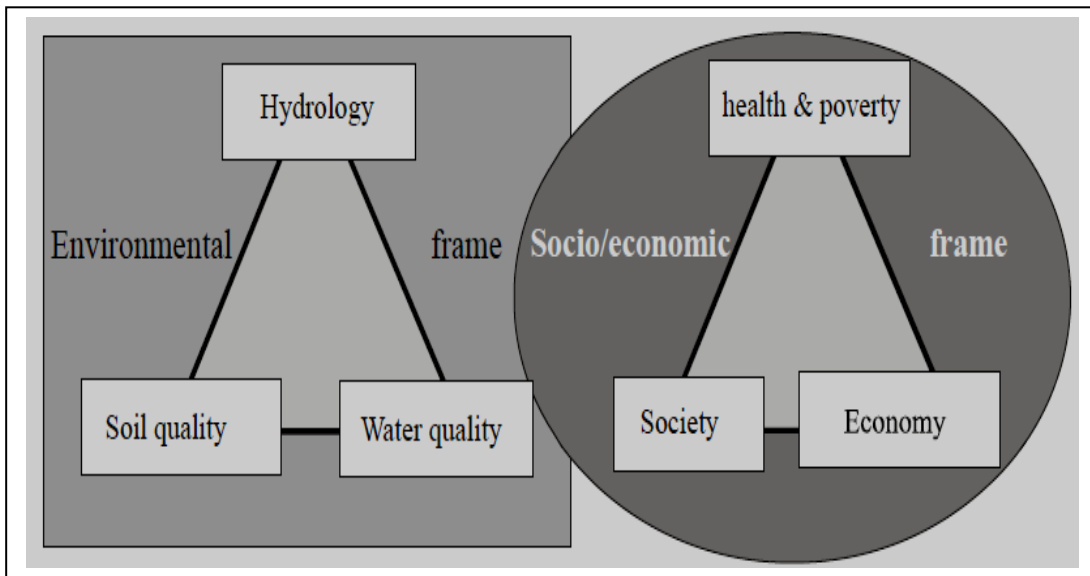


Figure 4.8: Environmental and socio-economic interaction (Awulachew, 2010)

The present study also revealed that farmers lack sustainable and secured financial capital that adversely affect their economic potential to invest in SSI. As a result, the sustainable development

of SSI is hindered and irrigators even relied on hand-mouth type of economy especially poor farmers, and sometimes depend on food aid during the chronic drought season. Thus, farmers should be financially well-off to enable them to invest in SSI and to improve the performance of rain-fed agriculture at the same time through the adoption of drought-tolerant crops in the study sites. Awulachew (2019) noted that the relatively high cost of irrigation farming creates a large investment risk for many smallholder farmers in Ethiopia, which hinders farmers continued investment in irrigation. SSI development should progress to low-input, effective, and sustainable irrigation development (Sakaki & Koga, 2013). The poor, elderly, and women found to be less benefited from the SSI. Yet, if a livelihood system is sustainable, it has to be coined with the principle of inclusive and equitable benefit for all groups of the community. Irrigation stimulates agricultural productivity and economic growth, but this may come at the cost of growing inequality (Van Den Berg & Ruben, 2006). Therefore, the Ethiopian government should work on designing projects or programs on building the financial capacity of the farmers on a sustainable, equity, and inclusive basis. Furthermore, the current study indicated the problem of technical sustainability of SSIS such as broken canals, PVC and motor pumps, blockage of canals with grass and soil, and ponds being full of sediments. These technical problems are responsible for the wastage of available water for the farmers as it is wasted before it reaches into farm fields. Aberra (2004) pointed out the major causes of technical unsustainability include poor project planning, lack of appropriate engineering studies, poor designing, lack of farmers participation at all levels of project planning, and implementation in his study at Tigray, Ethiopia. You (2008) concluded that it is only lower-cost irrigation technologies and approaches are viable in SSA. Programs that advocate and planned to introduce water-saving irrigation systems should be holistic and have the role to address farmers' day-to-day problems (Burnham *et al.*, 2015). The Ethiopian government should emphasize the introduction of appropriate irrigation technologies, which are farmer-friendly such as simple, quick, cheap, and safe to ensure the technical sustainability of SSIS.

On the other hand, climate variability found to be the cruel enemy that undermines the sustainability of irrigation-based rural livelihoods as the change is unpredictable with its devastating effects. The adoption of a strong watershed based development approach and environmental management activities can bring a solution to enhance sustainable development in the study sites. To mitigate the effect of rainfall variability in the area, crop water productivity

should be enhanced by increasing yields per unit of land, by adopting good agricultural practice, enhancing soil fertility, and pest control keeping into consideration the adverse environmental impacts to the minimum if possible preventing the adverse impacts. Furthermore, even for individual wells and rainwater harvesting, as more and more people start to irrigate, they impact other users in the watershed, and some form of coordination and rules governing water use can help prevent conflicts and give users some assurance that their investments in irrigation will be sustainable (Meinzen-Dick, 2014).

4.5 Conclusion

Small scale irrigation plays a vital role in improving the economic status, human capital development, availability of food for households, improving the housing condition and a means to cope up with the adverse effects of climate variability. Thus, SSI appears fitting to drought-prone areas to averse the unexpected or seasonal crop failure than those farmers who relied on rain-fed agriculture. However, the profitability of farmers' investment in SSI farming is constrained by its negative effects such as the prevalence of new pests, diseases, degradation of natural resources, and other socio-ecological threats. Therefore, strong government intervention is necessary for the provision of the right type of pesticide at an affordable price to enable farmers to protect crop loss. Farmers should be also assisted with better performing agricultural extension services with appropriate training packages on how to apply pesticides safely and the dose of the pesticide. The most important factor that hinders the enhancement of SSI is the volatile market price of the vegetables. The gain from irrigation can be optimized if agricultural input and output markets are managed by farmers' union without the involvement of middlemen.

Competition for water among multiple users results in water scarcity, which consequently brought conflict between upstream and downstream users. Women and elderly people have limited access to irrigation water. Moreover, water abstraction by large scale irrigation farms weakens the SSI farmers, which is related to the tragedy of the concept of the commons. However, equitable access to natural resources by the community is the key to the sustainable livelihood framework. Hence, applicable institutional interventions and legal laws are crucial to address the current dispute and inequitable water use among multiple users. Furthermore, the rural health extension program has to work and advocate fertility decline by making contraceptives accessible for the farming

community to reduce the burden on the natural resources. The expansion of large scale irrigation farms should be also controlled to ensure the sustainability of natural resources in the area.

The sustainable development of irrigated agriculture is compromised in the study sites due to the effect of multiple factors related to natural resources, economic, technical, social, and climate variability induced livelihood challenges. Addressing these multiple challenges at the grass-root level is the key to enhance sustainable development. Therefore, building sustainable irrigation-based rural livelihood should be given priority in agricultural policy in Ethiopia rather than mere advocacy of SSI expansion. If the irrigation-based rural livelihood ensures sustainable agricultural development, it enables the potential to address the current pressing livelihood challenges in the study sites including rainfall variability, recurrent drought, food insecurity, poverty, and natural resources degradation. This implies that in a sustainable irrigation-based livelihood the benefits of SSI outweigh its adverse effects in many ways. Furthermore, policymakers and implementers in the agricultural sector should focus on building a healthy socio-economic and environmental interface to ensure sustainable development.

Future researches are recommended on the effects of SSI farming on human health and biodiversity change with regress analysis. Besides, future researches are recommended to investigate the balance of irrigation water supply and demand in the CRV of Ethiopia. The effects of SSI expansion on non-irrigators is one of the future research topics that needs rigorous investigation.

Chapter 5: Synthesis

5.1 Introduction

Climate change and variability have become the critical challenge for the livelihood of millions people globally, whose livelihoods are dependent on agriculture (Mertz *et al.*, 2009). The impacts of climate change are highly disproportionate as the level of vulnerability and exposure varies across regions, agro-ecologic zones, and economic level of development. Accordingly, the livelihood of subsistence rain-fed dependent farmers in the SSA region is highly affected by the adverse effects of climate variability as there are lots of social, economic, environmental and policy issues that further aggravate the problem in this region (Komba & Muchapondwa, 2012; Mertz *et al.*, 2009). Therefore, simple dependency on rain-fed subsistence farming becomes no more reliable livelihood systems in the SSA region, whereby Ethiopia is not exceptional by any criteria. Consequently, many governments in SSA divert their attention towards introducing SSI to overcome climate variability induced livelihood challenges of rain-fed dependent subsistence farm households. Similarly, Ethiopia has given strong policy attention to the water sector and irrigation development especially SSI development has received more policy attention by the current government. In support of the policy attention, SSI development and expansion have been taken place in different parts of Ethiopia including the CRV area.

This study was undertaken in the CRV of Ethiopia, an area that is known for having globally and locally valuable ecosystem services based on the available lakes and wetlands. However, the area remained to be the challenges for the sustainability of the resources based on intragenerational and intergeneration aspects due to anthropogenic modifications coupling with climate variability. Small scale irrigation development was among the initiatives that have been undertaken to improve the livelihood of the community, alleviate poverty and improve food security situation by enhancing farmers' adaptive and resilience capacity to overcome the effects of climate variability. This research was undertaken to examine the environmental and socio-economic impacts of SSI development in the CRV area. The type and nature of impacts of the irrigation intervention can be affected by various factors. The forms of farmers' participation in irrigation farming and the management of the scheme and the performance of the local level irrigation institutions have their

role in determining the outcomes of the SSI projects. In this study, the analysis of the impacts of irrigation considered both positive and negative effects on livelihood, income, environmental resources such as soil, water and land, and social aspects. The framework of the analysis of the entire study was based on the approaches of sustainable livelihood development (Chambers, 1987; DFID, 2000).

This chapter presents the major findings, focused on the issues that need future policy and development intervention, and implication of the overall finding on sustainable rural livelihood development. It also forwards some policy implications and future research areas that stemmed from the results of the study.

5.2 Major findings

The climate-sensitive rain-fed subsistence farming of the smallholder farmers make the livelihood of the community vulnerable to the adverse effects of climate change and variability in the semi-arid parts of the CRV of Ethiopia. The current study (in chapter 2) revealed that smallholder farm households' participation in irrigation farming becomes mandatory. This is mainly because participation in SSI is not a random action as the decision of the farmers' to participate in SSI is determined by many complex and interdependent factors such as economic, social, natural, institutional, and policy issues. The study finding also highlighted that poor market access due to lack of road linkage is the major factor that adversely affected farmers' decision to work in irrigation. The main underlying problem in association with the market problem is that irrigated products that are dominated by vegetables and fruits are highly perishable unless they are immediately taken into the market once harvested. Besides, ensured land and water access rights, and access to credit services are key areas that need attention to enhance farmers' decision to participate in irrigation. Thus, it is possible to conclude that to enhance farmers' decision to participate in irrigation, the government has to work on creating a market and road access. Furthermore, the result of the current study (in chapter 2) revealed that irrigation user farmers have a better income than non-users. However, the amount of income of the farm HHs affected by multiple factors. Thus, all the significant factors that affect HH income should be taken into consideration while planning and introducing new irrigation projects among smallholder farmers.

The current study also indicated that farmers participate in different forms in irrigation scheme management like in the maintenance and operation of the scheme, financial contribution, labor contribution, and other aspects. Yet, the lack of transparency in the performance of the local level WUAs committee discourages farmers' full-scale participation in the planning, implementation, monitoring, and evaluation phase of the irrigation scheme. Therefore, designing strategies to monitor the performance of local level irrigation institutions needs further work to enhance farmers' trust in the local level irrigation management and to increase their participation in irrigation on a sustainable basis. In general, the binding point here is that without significant short-term production and/or income gains, farmers may not consider their participation in SSI to be worthwhile and sustainable.

The investigation on the effects of SSI on soil resources generally indicated that irrigation practices have adversely affected the soil of the farm fields. This study (in chapter 3) examined the state of soil salinity development, its causes, effects, and methods of reclaiming soils affected by salinity due to SSI farming induced factors. The finding provided empirical evidence in which the quality of irrigation water affects the development of soil salinity in the irrigated sites. Besides, the result further showed that the intensity of soil salinity development is different based on the type of irrigation water sources. In the study sites, farmlands irrigated with groundwater found to have sodic soils that are in line with the chemical characteristics of the sodic type of the water in the Bochesssa irrigation site. Therefore, gypsum and crop-based land reclamation measures need to be implemented to averse the negative effect of sodicity on crop production to enhance the sustainability of the benefits of SSI in the area.

On the other hand, the study revealed that waterlogging and associated sodicity development resulted in the loss of farmlands due to poor drainage systems at the Shelad irrigation site, which implies the need to introduce a farmer-friendly drainage system to avoid further loss of farmlands. In general, the study proofed that multiple factors aggravate the development of soil salinity in the investigated irrigation sites. Salinity affected productivity in irrigated fields in many ways and adversely affected the household economy. Thus, this is an alarm on the urgency to devise ameliorative techniques to encounter the pervasive soil salinity to ensure agricultural

sustainability. But, it is to be noted that area-specific soil salinity ameliorative techniques need to be developed as the problem and its impacts vary geographically. Moreover, adopting rice and other salts tolerant crop production systems is mandatory in waterlogged areas. The application of the gypsum amendment is also recommended as it is very economical and abundant in the area. The present study (in chapter 4) documented the various benefits of SSI in supporting the livelihood of farmers. Small scale irrigation development has supported farmers with various economic gains such as increased income compared to non-irrigators, human capital development, means of livelihood diversification, availability of food for households, improving the housing condition, employment creation, and a means to cope up with the effects of climate variability and drought risks. SSI appears fitting to drought-prone areas to averse the unexpected and seasonal crop failure than those farmers who relied on rain-fed agriculture.

On the other hand, the finding (chapter 4) showed that SSI has numerous negative effects on livelihood and environmental resources. These include the prevalence of new pests, diseases, degradation of natural resources, and other socio-ecological threats. Pests and weeds found to be serious problems, which discourage farmers' investment in irrigation on a sustainable basis. Farmlands and water resources are also negatively affected due to irrigation intervention. This problem has also aggravated the interference of urban residents investing in irrigation renting farmlands from poor farmers and the abstraction of water by large scale irrigation farms in the surrounding area. Limited access to input and output markets, expensive input prices, interference of brokers (middlemen) in the marketing process, nature of irrigation products (homogeneity and perishability), the volatile market price of irrigated products, lack of reliable irrigation water and associated conflicts are also the major challenges that hinder the enhancement of SSI farming in the upstream and downstream users of the study area (chapter 2 and 4). Moreover, water abstraction by large scale irrigation farms weakens the SSI farmers, which is related to the tragedy of the commons concept.

The study proofed that FHHs (chapter 2) have less participation in irrigation compared to MHHs. Irrigation water management practices such as night time crop watering and existing conflicts for water are not convenient for female farmers. Thus, most FHHs preferred to rent out their irrigable land while they work as a daily laborer in irrigated areas. The study further showed

that there is a limited or almost no participation of women as a committee member in local level WUAs. Therefore, gender-sensitive SSI farming practices and management options should be considered in future policies towards enhancing the equitable benefit of the technology. The study provides important empirical evidence about the interaction and interfaces between environment and socio-economic contexts under SSI farming households in the CRV of Ethiopia. Looking at the overall findings of the study, it is possible to draw implications for sustainable rural livelihood. The sustainability issue of livelihoods falls into two groups such as environmental and socio-economic sustainability. Environmental sustainability focuses on the internal capacity of livelihoods to withstand outside pressures and socio-economic sustainability refers to whether a human unit (individual, household, or family) cannot only gain but maintain an adequate and decent livelihood in terms of equity.

Depending on the overall finding it is possible to conclude that the current mechanism of smallholder irrigation farming practices doesn't have a significant implication to ensure sustainable rural livelihood if the existing irrigation system continues in the long run. Concerning environmental resources, the contribution of SSI to enhance sustainable rural livelihood system is hindered by salinity and degradation of soil resources which mainly resulted from intensive production and high dependency and over usage of chemicals like fertilizers and pesticides. Similarly, the degradation of agricultural water resources is the other hot spot identified by this research as a critical challenge that speeds up the doomsday of irrigation farming in the study sites let alone to think about the contribution of irrigation for sustainable livelihood. This problem is mainly related due to the hectic competition among smallholder irrigators and large scale irrigation farms for the same water resources.

According to the theory of 'tragedy of the commons' by Hardin (1968), in the case of a common-pool resource like water, the more powerful uses more resources while the less powerful have limited access to the resources. This is the case that has been happening in the CRV area, whereby the large scale private horticultural and floricultural firms pump a large quantity of water using their huge motors while small scale irrigators have limited access to the same water. For instance, this is a common challenge for smallholder irrigators dependent on Bulbula River especially during the dry season when the volume of Lake Ziway shrinks. The findings of this study also indicated

that (chapters 3 and 4), the big firms affect not only water abstraction but also discharge wastes into the water bodies which in turn affect the quality of irrigation water. Therefore, this unbalanced competition for agricultural water that drives from lack of equitable access for water has an adverse implication on the role of SSI towards the attainment of sustainable livelihood. Improved water security is thus central to improving people's resilience to climate variability and extreme weather events (Sadoff *et al.*, 2015). Moreover, the insecurity of accessing agricultural water is very acute especially during dry seasons when there is water scarcity. In such instances, elderly people and women are the most affected part of the community (chapter 4). This is also one dimension that shows the limitation of SSI to enhance sustainable development.

Besides, the water use mechanisms of the smallholder farmers have implications on the sustainability of irrigation farming. However, the data at hand do not support this assumption because most of the water conveyance systems are not efficient to discharge wastewater before it reaches the farmland due to a lack of proper maintenance. As pointed out by the Commission for Sustainable Development (CSD) in 2002 as cited in UN (2018), conservation and proper management of natural resources are the basic requirements of sustainable development. Therefore, to enhance sustainable development sensitivity towards saving agricultural water is the key that has to be implemented in SSI projects as a package.

The study showed that farmers' limited access to financial capital in the form of credit service is the number one challenge that hinders the enhancement of SSI on sustainable bases (chapter 4). The study also highlighted that poor market and road linkages further aggravate the problems of SSI to contribute to the achievement of the objectives of sustainable agriculture. Generally, the role of SSI farming towards the enhancement of sustainable livelihood is compromised due to the effect of multiple factors related to natural resources, socio-economic, technical, and climate variability induced livelihood challenges. Addressing these multiple challenges at the grass-root level is the key to enhance sustainable development. Therefore, building sustainable rural livelihood should be given priority in agricultural policy in Ethiopia rather than mere advocacy of SSI expansion. If the irrigation-based rural livelihood ensures sustainable agricultural development, it enables the potential to address the current pressing livelihood challenges in the study sites including rainfall variability, recurrent drought, food insecurity, poverty, and natural

resources degradation. However, SSI cannot bring a magic solution to sustainable rural development without considering the improvement of rain-fed agriculture because the lion share of the rural people's livelihood still depends on the rain-fed system. Thus, promoting the performance of both irrigation and rain-fed agriculture should be coined in the policies and implementations in Ethiopia.

5.3 Policy implication

The Ethiopian government has smart policies on irrigation and water sector development considering irrigation as a key strategy to overcome the adverse effects of climate change and variability on the livelihood of agricultural-based communities. The government gives particular attention to the expansion of small scale irrigation as the livelihood of subsistence rain-fed smallholder farmers is highly vulnerable to the risks and damaging effects of climate change. Accordingly, small scale irrigation has been expanding in different parts of the country with the support of government and NGOs. CRV of Ethiopia found to be among the areas in the country where there is an expansion of SSI for a long period. This study investigated the environmental and socio-economic impacts of the small scale irrigation practices in the CRV of Ethiopia.

The study found many issues that need future policy attention to achieve the predetermined goals from irrigation in implementing the irrigation and water sector development of the country. The study showed that SSI has both positive and negative effects on the livelihood of the community and environmental resources. The negative effects and the challenges of SSI development are numerous. Thus, future policies are critically important on how to mitigate those negative effects of SSI, otherwise, these unwanted consequences will continue to compromise the benefits of SSI. The study proofed that the simple provision of irrigation technology cannot bring the expected benefits from SSI without the intervention of supportive institutions. Irrigation is a capital intensive form of farming as it demands high input costs for pesticide, fertilizer, improved seed, and labor. These were found to be the big challenge that hinders the participation of farmers in SSI in the study area. Thus, policy considerations are vital on how to make financial institutions to be reachable for the farming community. In this regard, future policies should take into consideration on credit provision for irrigators under the intervention of government subsidies because the

farming communities are in fear of interest rate whenever they plan to take credit from financial institutions. The main rationale behind farmers' worry about loan repayment is that sometimes farmers cannot get income from irrigation as they expect due water scarcity, unexpected climate variability and/or market fluctuation, which affect their economic potential to pay the loan.

Small scale irrigation has benefited the farming community in various ways, however, the sustainability of the benefits of SSI seems gloomy due to many interrelated factors. Among these factors, agricultural water scarcity is a big challenge to sustain the benefits of SSI. The high water abstraction by the greedy private large scale irrigation farms escalates the problem of water scarcity among the smallholder farmers in addition to the existing high competition for water among multiple users. Thus, future policy attentions should be geared towards introducing a water pricing system for large scale irrigators based on the amount of water abstracted. This could be an important direction to enhance water users' behavior to adopt water-saving irrigation technologies. Furthermore, although SSI is introduced to support the livelihood of the rural farming community, in some of the study *Kebeles* the urban residents getting benefited investing in irrigation renting farmlands especially from poor farmers. Such practices constrained the poverty-reducing effect of irrigation as it makes the poor farmers less participant in irrigation. Hence, the Ethiopian government should design new policy interventions to manage the urban-rural interface, otherwise, irrigation may play its unintended goals making the rich richer and the poor poorer.

Although the government policy on agricultural development includes gender mainstreaming as its development direction, the study reflected the gender blindness of the implementation of irrigation projects in the study sites. The study proofed that women farmers get less income from irrigation, low participation as a committee member in WUAs, and less attendant of the meetings of WUAs. Thus, in future policy attentions, gender-sensitive policies have to be designed to create opportunities for women to participate in the planning, implementation, monitoring, and evaluation phases of irrigation projects. This needs immediate policy consideration, otherwise, it is impossible to attain the goal of sustainable agriculture and sustainable water resources development.

The study indicated that the lack of transparency in the performance of local irrigation institutions and limited participation of WUAs members at planning, implementation, monitoring, and evaluation of irrigation projects. Therefore, future policies should target strength and design mechanisms on how to follow up on the performance of irrigation institutions at different levels.

5.4 Significance of the study for academics and research

This research has tremendous contribution to be used as a good source of literature for academicians and researchers having the interest to read and undertake research investigation concerning SSI farming intervention, its environmental and socio-economic impacts, existing challenges, and the implication of SSI for sustainable rural livelihood. Most of the previous research works undertaken on SSI mainly deals with examining the contribution of SSI having limited attention to investigate the adverse effects of SSI projects. This can be one of the key contributions this research work to provoke future researchers to investigate the negative impacts of SSI in different parts of the world. This research can have significant methodological contributions making holistic and livelihood centered analysis using quantitative and qualitative data types collected using multiple tools such as survey, interview, laboratory analysis, and document review. This can be a good source for literature for mixed-method research design.

5.5 Future research areas

Based on the findings of the current study, the following future research areas are recommended.

1. The CRV of Ethiopia is one of the environmentally valuable areas in Ethiopia where there are ecologically valuable water resources and biodiversity-rich wetlands. However, the expansion of large scale private irrigation farms can be the future challenge for the sustainability of the area. Environmental impact assessment activities are key strategies to enhance the sustainability of the area. Thus, research investigations are important to what extent the current environmental impact assessment process is implemented by private irrigation farms in the CRV.

2. Water is a vital resource for all living beings and the ecosystem services, however, water resources are under a big threat due to anthropogenic and natural factors like climate change. Water scarcity is a global common problem and remained to be a future challenge for the global community. Therefore, community sensitivity towards water resources sustainability needs attention. Therefore, future research on water users' behavior, willingness to pay for water, and determinants of adoption of water-saving irrigation technology is essential.
3. Besides, future researches are recommended to investigate the balance of irrigation water supply and demand in the CRV of Ethiopia considering all other demands for water other than agriculture.
4. The current study was undertaken in the semi-arid environmental setting at CRV of Ethiopia investigating the socio-economic and environmental impacts of SSI. A different finding might result if the impact of irrigation is undertaken considering different agroecological systems.
5. The impact of irrigation on human health and biodiversity is not well investigated in this research, but it needs further investigation as it has its implication on the sustainability of irrigation-based livelihoods. Hence, future researches are recommended on the effects of SSI farming on human health and biodiversity change with regress analysis.
6. The study showed the existence of the gender gap in participation at irrigation, benefit-sharing, and participation in decision making roles in irrigation institutions. Future, researches are recommended on how to address the gender gaps in irrigation, irrigation technology preference of women, and to what extent women have the rights to access water and land rights.

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Appendices

Appendix I: Conversion factors used to compute Adult-Equivalent

Age group (years)	Sex group	
	Male	Female
<10	0.60	0.60
10-13	0.90	0.80
14-16	1.00	0.75
17-50	1.00	0.75
>50	1.00	0.75

Source: (Strok *et al.*, 1991)

Appendix II: Conversion factors used to estimate TLU Animal

Animal Category	Tropical Livestock Unit (TLU)
Calf	0.25
Donkey (young)	0.35
Weaned calf	0.34
Camel	1.25
Heifer	0.75
Goat/sheep (adult)	0.13
Cow and ox	1.0
Goats/sheep (young)	0.06
Horse	1.10
Donkey (adult)	0.70
Chicken	0.013

Source: (Strok *et al.*, 1991)

Appendix III: Least Significance Difference Test

Multiple Comparisons								
Dependent Variable	I	J	Mean Difference (I-J)	Std. Error	Sig.	Decision		
						Significance	Reason	
pH-H2O	LSD	Ground Water	River Bulbula	0.745	0.35097	0.06	NS	Sig> α
			River Ketar	1.55000*	0.35097	0.001	HS	Sig< $\alpha/2$
			Rain-fed	1.72667*	0.28657	0	HS	Sig< $\alpha/2$
		River Bulbula	Ground Water	-0.745	0.35097	0.06	NS	Sig> α
			River Ketar	.80500*	0.35097	0.045	S	Sig< α
			Rain-fed	.98167*	0.28657	0.006	S	Sig< α
		River Ketar	Ground Water	-1.55000*	0.35097	0.001	HS	Sig< $\alpha/2$
			River Bulbula	-.80500*	0.35097	0.045	HS	Sig< $\alpha/2$
			Rain-fed	0.17667	0.28657	0.551	NS	Sig> α
		Rain-fed	Ground Water	-1.72667*	0.28657	0	HS	Sig< $\alpha/2$
			River Bulbula	-.98167*	0.28657	0.006	S	Sig< α
			River Ketar	-0.17667	0.28657	0.551	NS	Sig> α
EC	LSD	Ground Water	River Bulbula	0.19	0.10669	0.105	NS	Sig> α
			River Ketar	0.025	0.10669	0.819	NS	Sig> α
			Rain-fed	0.18667	0.08711	0.058	NS	Sig> α
		River Bulbula	Ground Water	-0.19	0.10669	0.105	NS	Sig> α
			River Ketar	-0.165	0.10669	0.153	NS	Sig> α
			Rain-fed	-0.00333	0.08711	0.97	NS	Sig> α
		River Ketar	Ground Water	-0.025	0.10669	0.819	NS	Sig> α
			River Bulbula	0.165	0.10669	0.153	NS	Sig> α
			Rain-fed	0.16167	0.08711	0.093	NS	Sig> α
		Rain-fed	Ground Water	-0.18667	0.08711	0.058	NS	Sig> α
			River Bulbula	0.00333	0.08711	0.97	NS	Sig> α
			River Ketar	-0.16167	0.08711	0.093	NS	Sig> α
Exch.Na	LSD	Ground Water	River Bulbula	10.11000*	1.35754	0	HS	Sig< $\alpha/2$
			River Ketar	13.80500*	1.35754	0	HS	Sig< α

			Rain-fed	12.99333*	1.10842	0	HS	Sig< α		
		River Bulbula	Ground Water	-10.11000*	1.35754	0	HS	Sig< α		
			River Ketar	3.69500*	1.35754	0.021	HS	Sig< $\alpha/2$		
			Rain-fed	2.88333*	1.10842	0.026	HS	Sig< $\alpha/2$		
		River Ketar	Ground Water	-13.80500*	1.35754	0	HS	Sig< $\alpha/2$		
			River Bulbula	-3.69500*	1.35754	0.021	HS	Sig< $\alpha/2$		
			Rain-fed	-0.81167	1.10842	0.481	NS	Sig> α		
		Rain-fed	Ground Water	-12.99333*	1.10842	0	S	Sig< α		
			River Bulbula	-2.88333*	1.10842	0.026	S	Sig< α		
			River Ketar	0.81167	1.10842	0.481	NS	Sig> α		
Exch.K	LSD	Ground Water	River Bulbula	6.56500*	2.48675	0.025	S	Sig< α		
			River Ketar	7.88500*	2.48675	0.01	HS	Sig< $\alpha/2$		
			Rain-fed	5.32000*	2.03042	0.026	HS	Sig< $\alpha/2$		
		River Bulbula	Ground Water	-6.56500*	2.48675	0.025	HS	Sig< $\alpha/2$		
			River Ketar	1.32	2.48675	0.607	NS	Sig> α		
			Rain-fed	-1.245	2.03042	0.553	NS	Sig> α		
		River Ketar	Ground Water	-7.88500*	2.48675	0.01	HS	Sig< $\alpha/2$		
			River Bulbula	-1.32	2.48675	0.607	NS	Sig> α		
			Rain-fed	-2.565	2.03042	0.235	NS	Sig> α		
		Rain-fed	Ground Water	-5.32000*	2.03042	0.026	HS	Sig< $\alpha/2$		
			River Bulbula	1.245	2.03042	0.553	NS	Sig> α		
			River Ketar	2.565	2.03042	0.235	NS	Sig> α		
		Exch.Ca	LSD	Ground Water	River Bulbula	-5.715	8.1143	0.497	NS	Sig> α
					River Ketar	-26.64000*	8.1143	0.008	HS	Sig< $\alpha/2$
					Rain-fed	-7.735	6.6253	0.27	NS	Sig> α
River Bulbula	Ground Water			5.715	8.1143	0.497	NS	Sig> α		
	River Ketar			-20.92500*	8.1143	0.027	HS	Sig< $\alpha/2$		
	Rain-fed			-2.02	6.6253	0.767	NS	Sig> α		
River Ketar	Ground Water	26.64000*	8.1143	0.008	S	Sig< α				
	River Bulbula	20.92500*	8.1143	0.027	HS	Sig< $\alpha/2$				

			Rain-fed	18.90500*	6.6253	0.017	HS	Sig< α /2		
		Rain-fed	Ground Water	7.735	6.6253	0.27	NS	Sig> α		
			River Bulbula	2.02	6.6253	0.767	NS	Sig> α		
			River Ketar	-18.90500*	6.6253	0.017	HS	Sig< α /2		
Exch.Mg	LSD	Ground Water	River Bulbula	1.75	1.83951	0.364	NS	Sig> α		
			River Ketar	-2.74	1.83951	0.167	NS	Sig> α		
			Rain-fed	0.08	1.50196	0.959	NS	Sig> α		
		River Bulbula	Ground Water	-1.75	1.83951	0.364	NS	Sig> α		
			River Ketar	-4.49000*	1.83951	0.035	HS	Sig< α /2		
			Rain-fed	-1.67	1.50196	0.292	NS	Sig> α		
		River Ketar	Ground Water	2.74	1.83951	0.167	NS	Sig> α		
			River Bulbula	4.49000*	1.83951	0.035	S	Sig< α		
			Rain-fed	2.82	1.50196	0.09	NS	Sig> α		
		Rain-fed	Ground Water	-0.08	1.50196	0.959	NS	Sig> α		
			River Bulbula	1.67	1.50196	0.292	NS	Sig> α		
			River Ketar	-2.82	1.50196	0.09	NS	Sig> α		
		CEC	LSD	Ground Water	River Bulbula	16.94	9.90037	0.118	NS	Sig> α
					River Ketar	-15.195	9.90037	0.156	NS	Sig> α
					Rain-fed	-2.475	8.08362	0.766	NS	Sig> α
River Bulbula	Ground Water			-16.94	9.90037	0.118	NS	Sig> α		
	River Ketar			-32.13500*	9.90037	0.009	HS	Sig< α /2		
	Rain-fed			-19.41500*	8.08362	0.037	HS	Sig< α /2		
River Ketar	Ground Water			15.195	9.90037	0.156	NS	Sig> α		
	River Bulbula			32.13500*	9.90037	0.009	HS	Sig< α /2		
	Rain-fed			12.72	8.08362	0.147	NS	Sig> α		
Rain-fed	Ground Water			2.475	8.08362	0.766	NS	Sig> α		
	River Bulbula			19.41500*	8.08362	0.037	HS	Sig< α /2		
	River Ketar			-12.72	8.08362	0.147	NS	Sig> α		
Sum of Cations	LSD	Ground Water	River Bulbula	12.71	10.8395	0.268	NS	Sig> α		
			River Ketar	-7.695	10.8395	0.494	NS	Sig> α		

			Rain-fed	10.65667	8.85042	0.256	NS	Sig> α		
		River Bulbula	Ground Water	-12.71	10.8395	0.268	NS	Sig> α		
			River Ketar	-20.405	10.8395	0.089	NS	Sig> α		
			Rain-fed	-2.05333	8.85042	0.821	NS	Sig> α		
		River Ketar	Ground Water	7.695	10.8395	0.494	NS	Sig> α		
			River Bulbula	20.405	10.8395	0.089	NS	Sig> α		
			Rain-fed	18.35167	8.85042	0.065	NS	Sig> α		
		Rain-fed	Ground Water	-10.65667	8.85042	0.256	NS	Sig> α		
			River Bulbula	2.05333	8.85042	0.821	NS	Sig> α		
			River Ketar	-18.35167	8.85042	0.065	NS	Sig> α		
Exchangeable Sodium %(ESP)	LSD	Ground Water	River Bulbula	12.88000*	1.89632	0	HS	Sig< $\alpha/2$		
			River Ketar	25.47000*	1.89632	0	HS	Sig< $\alpha/2$		
			Rain-fed	23.10167*	1.54834	0	HS	Sig< $\alpha/2$		
		River Bulbula	Ground Water	-12.88000*	1.89632	0	HS	Sig< $\alpha/2$		
			River Ketar	12.59000*	1.89632	0	HS	Sig< $\alpha/2$		
			Rain-fed	10.22167*	1.54834	0	HS	Sig< $\alpha/2$		
		River Ketar	Ground Water	-25.47000*	1.89632	0	HS	Sig< $\alpha/2$		
			River Bulbula	-12.59000*	1.89632	0	HS	Sig< $\alpha/2$		
			Rain-fed	-2.36833	1.54834	0.157	NS	Sig> α		
		Rain-fed	Ground Water	-23.10167*	1.54834	0	HS	Sig< $\alpha/2$		
			River Bulbula	-10.22167*	1.54834	0	HS	Sig< $\alpha/2$		
			River Ketar	2.36833	1.54834	0.157	NS	Sig> α		
		ECsat.Ext	LSD	Ground Water	River Bulbula	.71500*	0.18364	0.003	HS	Sig< $\alpha/2$
					River Ketar	.70000*	0.18364	0.003	HS	Sig< $\alpha/2$
					Rain-fed	.92000*	0.14994	0	HS	Sig< $\alpha/2$
River Bulbula	Ground Water			-.71500*	0.18364	0.003	HS	Sig< $\alpha/2$		
	River Ketar			-0.015	0.18364	0.937	NS	Sig> α		
	Rain-fed			0.205	0.14994	0.202	NS	Sig> α		
River Ketar	Ground Water			-.70000*	0.18364	0.003	HS	Sig< $\alpha/2$		
	River Bulbula			0.015	0.18364	0.937	NS	Sig> α		

			Rain-fed	0.22	0.14994	0.173	NS	Sig> α		
		Rain-fed	Ground Water	-0.92000*	0.14994	0	HS	Sig< $\alpha/2$		
			River Bulbula	-0.205	0.14994	0.202	NS	Sig> α		
			River Ketar	-0.22	0.14994	0.173	NS	Sig> α		
Na	LSD	Ground Water	River Bulbula	4.79500*	0.7005	0	HS	Sig< $\alpha/2$		
			River Ketar	5.77000*	0.7005	0	HS	Sig< $\alpha/2$		
			Rain-fed	6.92500*	0.57196	0	HS	Sig< $\alpha/2$		
		River Bulbula	Ground Water	-4.79500*	0.7005	0	HS	Sig< $\alpha/2$		
			River Ketar	0.975	0.7005	0.194	NS	Sig> α		
			Rain-fed	2.13000*	0.57196	0.004	HS	Sig< $\alpha/2$		
		River Ketar	Ground Water	-5.77000*	0.7005	0	HS	Sig< $\alpha/2$		
			River Bulbula	-0.975	0.7005	0.194	NS	Sig> α		
			Rain-fed	1.155	0.57196	0.071	NS	Sig> α		
		Rain-fed	Ground Water	-6.92500*	0.57196	0	HS	Sig< $\alpha/2$		
			River Bulbula	-2.13000*	0.57196	0.004	HS	Sig< $\alpha/2$		
			River Ketar	-1.155	0.57196	0.071	NS	Sig> α		
		K	LSD	Ground Water	River Bulbula	0.575	0.37289	0.154	NS	Sig> α
					River Ketar	.90000*	0.37289	0.036	HS	Sig< $\alpha/2$
					Rain-fed	0.59333	0.30446	0.08	NS	Sig> α
River Bulbula	Ground Water			-0.575	0.37289	0.154	NS	Sig> α		
	River Ketar			0.325	0.37289	0.404	NS	Sig> α		
	Rain-fed			0.01833	0.30446	0.953	NS	Sig> α		
River Ketar	Ground Water			-.90000*	0.37289	0.036	HS	Sig< $\alpha/2$		
	River Bulbula			-0.325	0.37289	0.404	NS	Sig> α		
	Rain-fed			-0.30667	0.30446	0.338	NS	Sig> α		
Rain-fed	Ground Water			-0.59333	0.30446	0.08	NS	Sig> α		
	River Bulbula			-0.01833	0.30446	0.953	NS	Sig> α		
	River Ketar			0.30667	0.30446	0.338	NS	Sig> α		
Ca	LSD	Ground Water	River Bulbula	1.3	2.43913	0.606	NS	Sig> α		
			River Ketar	10.30000*	2.43913	0.002	HS	Sig< $\alpha/2$		

			Rain-fed	6.66667*	1.99154	0.007	HS	Sig< α /2		
		River Bulbula	Ground Water	-1.3	2.43913	0.606	NS	Sig> α		
			River Ketar	9.00000*	2.43913	0.004	HS	Sig< α /2		
			Rain-fed	5.36667*	1.99154	0.023	HS	Sig< α /2		
		River Ketar	Ground Water	-10.30000*	2.43913	0.002	HS	Sig< α /2		
			River Bulbula	-9.00000*	2.43913	0.004	HS	Sig< α /2		
			Rain-fed	-3.63333	1.99154	0.098	NS	Sig> α		
		Rain-fed	Ground Water	-6.66667*	1.99154	0.007	HS	Sig< α /2		
			River Bulbula	-5.36667*	1.99154	0.023	HS	Sig< α /2		
			River Ketar	3.63333	1.99154	0.098	NS	Sig> α		
		Mg	LSD	Ground Water	River Bulbula	2.20000*	0.92159	0.038	HS	Sig< α /2
					River Ketar	4.30000*	0.92159	0.001	HS	Sig< α /2
Rain-fed	3.13333*				0.75248	0.002	HS	Sig< α /2		
River Bulbula	Ground Water			-2.20000*	0.92159	0.038	HS	Sig< α /2		
	River Ketar			2.10000*	0.92159	0.046	HS	Sig< α /2		
	Rain-fed			0.93333	0.75248	0.243	NS	Sig> α		
River Ketar	Ground Water			-4.30000*	0.92159	0.001	HS	Sig< α /2		
	River Bulbula			-2.10000*	0.92159	0.046	HS	Sig< α /2		
	Rain-fed			-1.16667	0.75248	0.152	NS	Sig> α		
Rain-fed	Ground Water			-3.13333*	0.75248	0.002	HS	Sig< α /2		
	River Bulbula			-0.93333	0.75248	0.243	NS	Sig> α		
	River Ketar			1.16667	0.75248	0.152	NS	Sig> α		
Sum of Cations	LSD	Ground Water	River Bulbula	8.87000*	2.78365	0.01	HS	Sig< α /2		
			River Ketar	21.28000*	2.78365	0	HS	Sig< α /2		
			Rain-fed	17.31833*	2.27284	0	HS	Sig< α /2		
		River Bulbula	Ground Water	-8.87000*	2.78365	0.01	HS	Sig< α /2		
			River Ketar	12.41000*	2.78365	0.001	HS	Sig< α /2		
			Rain-fed	8.44833*	2.27284	0.004	HS	Sig< α /2		
		River Ketar	Ground Water	-21.28000*	2.78365	0	HS	Sig< α /2		
			River Bulbula	-12.41000*	2.78365	0.001	HS	Sig< α /2		

			Rain-fed	-3.96167	2.27284	0.112	NS	Sig> α		
		Rain-fed	Ground Water	-17.31833*	2.27284	0	HS	Sig< $\alpha/2$		
			River Bulbula	-8.44833*	2.27284	0.004	HS	Sig< $\alpha/2$		
			River Ketar	3.96167	2.27284	0.112	NS	Sig> α		
Carbonate	LSD	Ground Water	River Bulbula	0	0.4213	1	NS	Sig> α		
			River Ketar	-0.395	0.4213	0.371	NS	Sig> α		
			Rain-fed	-0.33	0.34399	0.36	NS	Sig> α		
		River Bulbula	Ground Water	0	0.4213	1	NS	Sig> α		
			River Ketar	-0.395	0.4213	0.371	NS	Sig> α		
			Rain-fed	-0.33	0.34399	0.36	NS	Sig> α		
		River Ketar	Ground Water	0.395	0.4213	0.371	NS	Sig> α		
			River Bulbula	0.395	0.4213	0.371	NS	Sig> α		
			Rain-fed	0.065	0.34399	0.854	NS	Sig> α		
		Rain-fed	Ground Water	0.33	0.34399	0.36	NS	Sig> α		
			River Bulbula	0.33	0.34399	0.36	NS	Sig> α		
			River Ketar	-0.065	0.34399	0.854	NS	Sig> α		
		Bicarbonate	LSD	Ground Water	River Bulbula	-2.855	2.17957	0.22	NS	Sig> α
					River Ketar	5.56000*	2.17957	0.029	HS	Sig< $\alpha/2$
					Rain-fed	2.52333	1.77961	0.187	NS	Sig> α
				River Bulbula	Ground Water	2.855	2.17957	0.22	NS	Sig> α
					River Ketar	8.41500*	2.17957	0.003	HS	Sig< $\alpha/2$
					Rain-fed	5.37833*	1.77961	0.013	HS	Sig< $\alpha/2$
River Ketar	Ground Water			-5.56000*	2.17957	0.029	HS	Sig< $\alpha/2$		
	River Bulbula			-8.41500*	2.17957	0.003	HS	Sig< $\alpha/2$		
	Rain-fed			-3.03667	1.77961	0.119	NS	Sig> α		
Rain-fed	Ground Water			-2.52333	1.77961	0.187	NS	Sig> α		
	River Bulbula			-5.37833*	1.77961	0.013	HS	Sig< $\alpha/2$		
	River Ketar			3.03667	1.77961	0.119	NS	Sig> α		
Chloride	LSD	Ground Water	River Bulbula	4.48500*	1.63696	0.021	HS	Sig< $\alpha/2$		
			River Ketar	5.15000*	1.63696	0.01	HS	Sig< $\alpha/2$		

		River Bulbula	Rain-fed	4.73500*	1.33657	0.005	HS	Sig< α /2		
			Ground Water	-4.48500*	1.63696	0.021	HS	Sig< α /2		
			River Ketar	0.665	1.63696	0.693	NS	Sig> α		
		River Ketar	Rain-fed	0.25	1.33657	0.855	NS	Sig> α		
			Ground Water	-5.15000*	1.63696	0.01	HS	Sig< α /2		
			River Bulbula	-0.665	1.63696	0.693	NS	Sig> α		
		Rain-fed	Rain-fed	-0.415	1.33657	0.763	NS	Sig> α		
			Ground Water	-4.73500*	1.33657	0.005	HS	Sig< α /2		
			River Bulbula	-0.25	1.33657	0.855	NS	Sig> α		
		Sulphate	LSD	Ground Water	River Bulbula	8.75000*	1.27697	0	HS	Sig< α /2
					River Ketar	15.83500*	1.27697	0	HS	Sig< α /2
					Rain-fed	14.73000*	1.04264	0	HS	Sig< α /2
River Bulbula	Ground Water			-8.75000*	1.27697	0	HS	Sig< α /2		
	River Ketar			7.08500*	1.27697	0	HS	Sig< α /2		
	Rain-fed			5.98000*	1.04264	0	HS	Sig< α /2		
River Ketar	Ground Water			-15.83500*	1.27697	0	HS	Sig< α /2		
	River Bulbula			-7.08500*	1.27697	0	HS	Sig< α /2		
	Rain-fed			-1.105	1.04264	0.314	NS	Sig> α		
Rain-fed	Ground Water			-14.73000*	1.04264	0	HS	Sig< α /2		
	River Bulbula			-5.98000*	1.04264	0	HS	Sig< α /2		
	River Ketar			1.105	1.04264	0.314	NS	Sig> α		
Sum of Anions	LSD	Ground Water	River Bulbula	10.18500*	3.56215	0.017	HS	Sig< α /2		
			River Ketar	25.95500*	3.56215	0	HS	Sig< α /2		
			Rain-fed	21.47000*	2.90848	0	HS	Sig< α /2		
		River Bulbula	Ground Water	-10.18500*	3.56215	0.017	HS	Sig< α /2		
			River Ketar	15.77000*	3.56215	0.001	HS	Sig< α /2		
			Rain-fed	11.28500*	2.90848	0.003	HS	Sig< α /2		
River Ketar	Ground Water	-25.95500*	3.56215	0	HS	Sig< α /2				
	River Bulbula	-15.77000*	3.56215	0.001	HS	Sig< α /2				

Sodium Adsorption Ratio % (SAR)			Rain-fed	-4.485	2.90848	0.154	NS	Sig> α
		Rain-fed	Ground Water	-21.47000 ^a	2.90848	0	HS	Sig< $\alpha/2$
			River Bulbula	-11.28500 ^a	2.90848	0.003	HS	Sig< $\alpha/2$
			River Ketar	4.485	2.90848	0.154	NS	Sig> α
	LSD	Ground Water	River Bulbula	1.47	1.0593	0.195	NS	Sig> α
			River Ketar	0.1	1.0593	0.927	NS	Sig> α
			Rain-fed	1.55167	0.86491	0.103	NS	Sig> α
		River Bulbula	Ground Water	-1.47	1.0593	0.195	NS	Sig> α
			River Ketar	-1.37	1.0593	0.225	NS	Sig> α
			Rain-fed	0.08167	0.86491	0.927	NS	Sig> α
		River Ketar	Ground Water	-0.1	1.0593	0.927	NS	Sig> α
			River Bulbula	1.37	1.0593	0.225	NS	Sig> α
			Rain-fed	1.45167	0.86491	0.124	NS	Sig> α
		Rain-fed	Ground Water	-1.55167	0.86491	0.103	NS	Sig> α
			River Bulbula	-0.08167	0.86491	0.927	NS	Sig> α
River Ketar	-1.45167		0.86491	0.124	NS	Sig> α		

Appendix IV: Soil salinity-sodicity decision table

ESP/EC	29.69	16.81	7.105	4.22	5.815
0.35	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil
0.16	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil
0.1	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil
0.215	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil
0.045	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil
0.325	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil
0.27	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil
0.345	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil
Area of sample	Groundwater	Bulbula	Rain-fed around Bulbula	Ketar	Rain-fed around ketar
Decision	Sodic (Alkaline) soil	Sodic (Alkaline) soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil	Non-Saline and Non-Sodic soil

Appendix V: Household survey questionnaire

Addis Ababa University
College of Development Studies
Center for Environment and Development Studies
A survey questionnaire for a PhD study on “**Environmental and Socio-economic Impacts of Small Scale Irrigation in the Central Rift Valley of Ethiopia**”

Household survey questionnaire consent form

Dear participant,

The survey questionnaire attached with this consent form is a data collection tool for the purpose of a PhD study. The research is undertaken as requirement for a PhD dissertation in Environment and Development field of specialization, college of Development Studies at Addis Ababa University. The title of the PhD dissertation is “Environmental and Socio-economic Impacts of Small Scale Irrigation Farming Households in the Central Rift Valley of Ethiopia.” The purpose of the questionnaire is to collect demographic, socio-economic and biophysical data from both irrigator and non-irrigator farmers to analyze the effect of irrigation from societal, environmental and economic aspects. Dear respondents, the result of this study will help different stakeholders and policy makers to make appropriate measures to enhance the contribution of small scale irrigation to ensure the goal of sustainable development in the areas where there is rainfall variability and drought occurrence. Your responses are confidential, your names are not written in the research and everything is kept anonymous. The household survey questionnaire is filled by trained enumerators based on your resources for the respective questions. Therefore, I kindly request you to participate in the household survey data collection.

Do you consent to participate in the household survey? Yes No

Therefore, you are kindly requested to provide genuine responses. Thank you for your time and cooperation!

General information

Zone _____ Woreda _____ Kebele _____ Respondent Code _____
Name of enumerator _____ Date _____

No.	Demographic characteristics of the household	Indicators/measurements	Answers
-----	--	-------------------------	---------

1.1.	Age	----- (in years)	
1.2.	Sex	1= Male 2= Female	
1.3.	Marital Status	1=Married 4=Widowed 2= Single 5=Polygamy 3=Divorced	
1.4	Have you attended formal education?	1= Yes 2= No	
1.5.	If your answer for Q. No 1.4 is yes, what is the highest grade level you attended?	_____ grade	
1.6.	Family size under different age category	_____ <14 years old (in number) _____ 15-64 years old (in number) _____ ≥ 65 years old(in number)	
1.7.	Major occupation of the Household head(multiple response is possible)	1=Crop production 3= Animal husbandry 4= Trading 5= Daily laborer 6=Government employment 7=Others, specify_____	

1. Households' demographic characteristics

2. Agricultural Extension and Credit Services

2.1.Have you visited by an extension agent in the last production year?

1= Yes 2= No

2.2.If your answer for Q. No 2.1 is 'Yes', what type of support do you get from extension agent (multiple response is possible)?

1= Farming system 2= Seed selection
3= Fertilizer application 4= Soil and water conservation
5=Irrigation water application 6=If, others, specify_____

2.3. How often do you contact the extension agents?

1=Once a week 4= Three times a month
2=Once a month 5= Others, specify_____

2.4.Have you ever taken credit? 1= Yes 2=No

2.5. If your answer for Q.No 2.4 is 'Yes' for what purpose did you use the credit (multiple response is possible)?

1=To purchase livestock 2=To construct housing
3=To purchase seeds 4= To purchase fertilizer
5= Others, specify_____

3. Land resource ownership and utilization

3.1.Do you have land for production and other activities? 1=Yes 2= No

3.2 If your answer for Q.No 3.1 is 'Yes', provide the following information about your land.

No	Type of land use	Land ownership type	Area in timad

1	Cultivable		
1.1	Irrigation land	Owned	
		Rented	
1.2	Rain-fed	Owned	
		Rented	
Other land uses			
2	Homestead	1=Yes 2=No	
3	Fallow	1=Yes 2=No	
4	Private pasture	1=Yes 2=No	
5	Private tree planting	1=Yes 2=No	
6	Common grazing land	1=Yes 2=No	

3.3 What type of fertilizer do you use for most of your crop production (multiple response is possible)?

1=DAP 2=Urea 3= Compost

3.4 Have you used improved seeds in the past production year? 1= Yes 2= No

3.5 If you do not ever used improved seeds, why (multiple response is possible)?

1= Too expensive to buy 2= Not available

3= Not better than the local ones 4= Not aware

5= If others, specify _____

3.6. Have you used pesticides in the past production year? 1=Yes 2=No

3.7. If your answer for Q. No 3.6 is 'No', why (multiple response is possible)?

1= Too expensive 2= Not available

3= Not aware 4= Others, specify _____

4. Rainfall and drought situations (based on farmers' view)

4.1. How do you evaluate sufficiency of rainfall of the area for crop production?

1=Excess 2=Sufficient 3=Insufficient 4=Very low

4.2.What looks like the pattern of rainfall in the area?

1=Decrease 2=Increase 3=Highly variable 4=No difference

4.3. Is there any record of crop failure in the area due to rainfall variability?

1=Yes 2=No

4.4.If your answer for Q. No 4.3 is 'Yes', indicate the years_____

4.5. Is there any record of occurrence of drought in your area? 1=Yes 2=No

4.6. If your answer for Q. No 4.5 is 'Yes', indicate the years_____

4.7.What were the effects of the drought in your locality?

1=Crop failure 2=Death of livestock

3= Food insecurity 4= Death of human beings

5=If others, specify_____

5. Small Scale Irrigation Farming Practices

- 5.1. For how long (years) you practiced irrigation? _____
- 5.2. How many times you produce annually by applying irrigation?
1=Once 2=Twice 3=Thrice 4=Others, _____
- 5.3. Do you farm your entire irrigable land holding? 1= Yes 2= No
- 5.4. If your answer for Q.No 5.3 is 'No', why? (Multiple response is possible)
1= Shortage of water 2= Low productivity of irrigation
3= Getting sufficient produce by rain feed 4= Poor quality of irrigation crops
5= Poor maintenance of irrigation scheme 6= Others, specify _____
- 5.5. From which water source do you irrigate the great proportion of your irrigated farm land?
1= River 2= Lake
3=Ground water 4= Harvested rain water
5=If others, specify _____
- 5.6. What type of Irrigation method do you use?
1= Furrow 2= Flood 3= If others, specify _____
- 5.7. How do you determine the sufficiency of irrigation water depth?
1= Flood over the field 2= Filling furrow 3= If others, specify _____
- 5.8. Do you have a method to estimate the amount of irrigation water? 1=Yes 2= No
- 5.9. Do you make any payment for irrigation services? 1=Yes 2=No
- 5.10. If your answer for Q.No 5.9 is 'Yes', how much do you pay? _____ in Birr
- 5.11. How do you pay? 1=Per month 2=Per quarter 3= Per plot
4= Per quantity of water 5=If other, specify _____
- 5.12. Is the amount of water you use for irrigation adequate for your production 1=Yes 2=No
- 5.13. If your answer for Q. No 5.12 is 'No', do you think your yield is reduced because you cannot apply enough water to your crop?
1=Yes 2=No
- 5.14. Is there difference in the amount of water you use for irrigation at different cropping season? 1=Yes 2=No
- 5.15. If your answer for Q. No 4.14 is 'Yes', what crops do you usually cultivate during the cropping season of less water amount?
1. _____ 2. _____ 3. _____ 4. _____
- 5.16. Why do you choose the specific crop based on your response to Q. No 5.15?
1=Less water demand 2=Better market price
3= Good production 4= High disease tolerance
5= Easy to cultivate 6=Seed availability
7=Others, specify _____
- 5.17. Do you use irrigation water for drinking as well? 1=Yes 2=No
- 5.18. What is the water conveyance method from source to field?
1=Concrete canal 2=Earthen canal (not concrete)
3=Flood 4=Plastic covered canal

5.19. How do you lift water from the source?

1=Motorized pump

2=Hand pump

3=Foot pump

4=Pipe

5.20. Do you think your water conveyance system is water saving? 1=Yes 2=No

6. Cropping information

6.1. Please List details for agricultural production during the last production year based on crop type (Non-irrigation user)

Crop type	Inputs used in the last Production year 2008												Production			
	Plot area		Seed		Fertilizer		Pesticide		Labour		Animal power		Total production		Income from the Sell of crops	
	(Tima d)	Cost (Br)	Amt(kg)	Cost(Br)	kg	Cost(Br)	Liter	Cost (Br)	Man day	Cost (Br)	Oxen day	Cost (Br)	kg	Cost (Br)	kg	Cost (Br)
Maize																
Teff																
Wheat																
Sorghum																
Barely																
Haircoat Bean																
Horse Bean																

6.2. Please List details for agricultural production during the last production year for each crop type (Irrigation user)

Crop type	Amt. of Water applied	1=full irrigation 2=supplemental irrigation 3=Rain-fed	Inputs used in the 2008 Production year of Irrigation users														Production in 2008 Production year	
			Plot area		Seed		Fertilizer		Pesticide and herbicide		Labour		Animal power		Total Production		Income from the Sell of crops	
			Amt(Ti mad)	Cost(Br)	Amt(kg)	Cost (Br)	Amt(kg)	Cost (Br)	Amt(kg)	Cost (Br)	Man day	Cost (Br)	Oxen day	Cost (Br)	Amt(kg)	Cost (Br)	Amt (kg)	Cost (Br)
Maize																		
Teff																		

Wheat																		
Sorghum																		
Barely																		
Tomato																		
Onion																		
Cabbage																		
Carrot																		
Green Pepper																		
Haircoat Bean																		
Soya Bean																		
Horse Bean																		
Water melon																		
Lettuce																		

7. Livestock Ownership

7.1. Do you own livestock? 1=Yes 2=No

7.2. If your answer for Q. No 7.1 is 'Yes', please provide the following information.

Livestock Owned in the last production year		No.	Value(Br)	Value consumed(Br)	Income from sell of animal (Br)
Cattle	Calf				
	Young Bull				
	Heifer				
	Cow				
	Draft oxen				
Sheep and goat	Sheep				
	Goat				
Equines	Horse				
	Donkey				
	Mule				
	Camel				
Poultry	Poultry				
Grand Total					

7.2 Income from livestock products in the last production year

Income from livestock products and others	Total income from sell (in Birr)
Dairy products (milk butter, cheese)	
Eggs	
Honey	
Fishing	
Others	
Sub-total	

Do you have non-farm source of income? 1=Yes 2=No

8.1 If your answer for Q.No 8 is 'Yes', please provide all income from non-farm sources.

Income from non-farm sources	Annual income(Birr)
Wage labor	
Petty trade	

Have you perceived any of the following in your locality due to effect of irrigation farming practices?	1=Yes 2=No 3=Not sure
Inefficient usage of water due to leakage from canal breakage	
Faulty use of irrigation water, over watering than required by the crop	
Risk of rising water table	
Seepage	
Formation of stagnant water that provide breeding areas for disease vectors	
Increased risk of flooding in the area	
Eutrophication of water bodies	
Reduce the quality of water in the water bodies	
Shrink the volume of Lake Ziway	
Decrease in the availability and quality of water for livestock	
Deterioration of the quality of human drinking water	
Reduce the accessibility of ground water	

9.7 Status of water resource

9.8 Have you ever adopted or introduced techniques to minimize the adverse effects of irrigation on water resources in your locality? 1=Yes 2=No

9.9 If your answer for Q.No 9.8 is 'Yes', what are those techniques?

9.10 Have you ever converted your tree planting land and pasture land to irrigable land?

1=Yes 2=No

9.11 If your answer for Q. No 9.7 is 'Yes', please provide the area of land.

Land converted from tree planting to irrigable land _____ in timad.

Land converted from pasture land to irrigable land _____ in timad.

9.12 Have you observed any of these due to irrigation development in your locality?

1= Encroachment to swamp and wetlands ecosystem

2= Conflicts in land tenure and land-use rights

3= Increase restoration of forest cover

4= Conflicts in water use rights

5=If others, specify _____

9.13 Have you perceived effect of irrigation on the biodiversity in your area? 1=Yes 2= No

9.22 Has your participation in irrigation agriculture created better opportunity with respect to the following? Please give explanation for your answer. Multiple responses are possible.

1= Asset building

2=Educating children

3=Livelihood diversification

4= Better health

10 Household wealth indicators

10.1 What is the condition of your house?

1= Corrugated Iron sheet roofed

2=Grass roofed

3= Both types

10.2 Where does your house located?

1= Rural area

2=Town

3=Both town and rural area

10.3 Do you educate your children? 1= Yes 2=No

10.4 If your answer for Q.No 10.3 is 'yes', where do you educate your children?

1=Rural area

2=Town

3= Both rural and urban

10.5 Do you save money at bank?

1= Yes

2= No

10.6 If your answer for Q.No. 10.5 is 'yes', how do you rate your saving habit?

1. Always

2. Sometimes

3. Rarely

4. Never

10.7 Are you able to provide food for your household throughout the year?

1. Yes

2. No

10.8 If your answer for Q.No. 10.7 is "yes", how often you are able to provide food for your household?

1. Always

2. Sometimes

3. Rarely

4. Never

10.9 Do you have the habit of saving money at financial institution? If so, how often do you save money?

1. Always

2. Sometimes

3. Rarely

4. Never

10.10 Do you use hired labour for your agricultural activities?

2. Yes

2. No

10.11 If your answer for Q.No. 10.7 is "yes", how often do you use hired labour for your agricultural activities?

1. Always

2. Sometimes

3. Rarely

4. Never

11. Effects of irrigation (irrigators only)

11.1 In your view, in what ways your participation in small scale irrigation affects your livelihood positively?

Livelihood contribution of small scale irrigation for the farming community: Irrigators view	1=Yes 2=No 3=Not sure
Better food availability during dry spells for HH consumption	
Improvement in agricultural production	
Increase HH income	
Contribute to livelihood diversification	
Resist/coping drought situation	
Purchase livestock (Oxen, cows, goats and others)	
Purchase household assets (Sofa, Television, motor cycle)	
Build houses in urban areas	
Construct houses with corrugated iron sheet roofs	
Use credit and pay back credit	
Enable saving money at saving institutions	
Cover educational costs of children properly	
Create employment opportunity	
Increase agricultural labour wage	

11.2 In your view, in which aspects small scale irrigation farming affects the community negatively?

Negative effects of irrigation farming on the farming community and environmental resources: Irrigators view	1=Yes 2=No 3=Not sure
Growth of new weeds	
Prevalence of crop disease and pests	
Prevalence of animal disease	
Prevalence of human disease and harms to human	
Land fertility declines	
Degradation of water resources	
Water logging due to seepage	
Increased soil salinity	
Introduction of exotic species of plant	
Drive out indigenous species of plant	
Reduction of the local biodiversity	

11.3 In your view, what are the major challenges that constrain the enhancement of small scale irrigation farming in your community?

Challenges of SSI agriculture: Irrigators view	1= Yes 2= No 3= Not sure
Market saturation	
Irregular financial returns	
Conflicts on water use rights	
Lack of road access	
Expensive irrigation input prices	
Interference of brokers in the marketing process of irrigated products	
Lack of reliable irrigation water source	
Lack of transparency in the performance of local level WUAs committee	

Appendix VI: FGD and interview guides

Introduction

I am a PhD student at Addis Ababa University; I am working on a research entitled as “Environmental and Socio-economic Impacts of Small Scale Irrigation in the Central Rift Valley of Ethiopia.” The purpose of the research is to examine the environmental and socio-economic impacts of small scale irrigation projects. More specifically, the research aims to investigate the effects of small scale irrigation on soil, livelihood, income and existing gender dynamics in the participation on irrigation. It also aims to investigate the forms of farmers’ participation in irrigation and the management of the schemes. Thus, this focus group discussion is helpful to get the information about the climate variability, rainfall pattern and drought condition of the area, and the significance of irrigation for smallholder farmers in the CRV area. So, your participation is highly useful for this study and I kindly request you to participate as FGD participant.

Thank you for your time and insights!

A) Mixed group (irrigation users and non-user farmers)

1. What looks like the condition of climate variability, rainfall pattern and drought occurrence in your locality?
2. Do you think that rainfall variability and drought being a serious issue in relation to your agricultural practices in your locality? If so, why?
3. Has rainfall variability and/or drought occurrence adversely affected your crop and livestock production sector in your locality? If so, to what extent the effects are serious in distracting the livelihood system of the farming community?
4. Small scale irrigation have been expanding in your locality in different forms since long time in the past. How do you see the role of SSIS development in your locality? Are SSIS really important in your local context?
5. What is the wealth indicator used to classify the community into different wealth rankings in your locality?
6. In your view, do you think that farming households working in irrigation have a better livelihood status compared to non-irrigation user farmers. What are the major indicators used by the community to identify the difference among the two groups of farmers?
7. What factors determine farmers' participation in irrigation agriculture? What are the challenges and opportunities that affect farmers' decision to work in irrigation?
8. What interventions do you recommend to enhance the participation of farmer to in irrigation farming in your locality?

B) Irrigation user farmers only

1. How SSI affects the livelihood, food availability and dietary type, and agricultural production (yield and type) in your locality? Are the effects positive or negative, if any? Please discuss all.
2. How does small scale irrigation farming affect environmental resources (soil, land productivity, pasture land and forest cover) of your local area? Compare the situation in rain-fed and irrigation farming practices and/or the situation before and after the introduction of irrigation in your locality. Discuss the positive and negative effects, if any.
3. Have you ever observed the development of soil salinity in your area? If so, what do you think are the causes, and how farmers respond to the soil salinity problem, if any?
4. Have you ever observed the prevalence of pests and diseases, animal and human health problem, biodiversity modification and other changes in your locality due to the effect of irrigation projects? If so, please discuss how and why such association exist?
5. Based on your response for question number 4, how do you evaluate the severity of these diseases? Please give examples of the series health problems that outbreak in your area frequently due to effect of irrigation. What has been done to solve the problem?

6. In your view do you think the current irrigation practices are water saving system considering water application interval and amount of water, field water management, irrigation schedule, maintenance and operation of the system?
7. Has irrigation ever caused conflict among farmers in your locality? If so, what were the major causes? How the conflicts were settled?
8. Do you think irrigation farming is equally beneficial on equity bases for women, men, the poor and rich farmers? Please elaborate the situation using examples.
9. What looks like the participation of farmer being a member of WUAs? Is there equal participation among farmers? How?
10. How do you evaluate the performance of WUAs committee members in the view transparency? Please elaborate using examples from what you observed in practice.

Interview guides

Introduction

I am a PhD student at Addis Ababa University; I am working on a research entitled as “Environmental and Socio-economic Impacts of Small Scale Irrigation in the Central Rift Valley of Ethiopia.” The purpose of the research is to examine the environmental and socio-economic impacts of small scale irrigation projects. More specifically, the research aims to investigate the effects of small scale irrigation on soil, livelihood, income, challenges the women face in participating at irrigation and decision making roles in the water users associations. It also aims to investigate the forms of farmers’ participation in irrigation, the management of the schemes. Thus, the interviews are helpful to get valuable information regarding farmers’ participation in small scale irrigation, challenges that women face while participating in irrigation and effects of irrigation on soil, livelihood, income and other impacts in the community in CRV area. This interviews are conducted with households (female household heads and male household heads, district experts and bureau heads. So, your participation is highly useful for this study and I kindly request you to participate in the interview.

Thank you for your time and insights!

A) Farmers’ interview guide for male household heads

1. What is the effect of irrigation on your agricultural productivity, household income, expenditure and livelihood diversification? Discuss the positive and negative effects if any.
2. What are the major problems of the upstream and downstream farmers? Who are the losers and beneficiaries?
3. What are the human, animal and crop diseases that are caused because of irrigation in your locality? How do you evaluate the severity of these diseases? Please give examples of the

series health problems that outbreak in your area frequently due to effect of irrigation. What has been done to solve the problem?

4. How does small scale irrigation practice affect natural resources (soil, land productivity, pasture land and forest cover) of your local area? Compare the situation in rain-fed and irrigation farming practices and/or the situation before and after the introduction of irrigation.
5. Have you observed salinity development in your soil? If so, what do you think the cause for the problem?
6. In your view do you think the current irrigation practices are water efficient or water saving system considering water application interval and amount of water, field water management, irrigation schedule, maintenance and operation of the system?
7. Has irrigation ever caused conflict among farmers in your locality? If so, what were the major causes? How the conflicts were settled?
8. Do you think irrigation farming is equally beneficial on equity bases for women, men, the poor and rich farmers?
9. What are the benefits and costs of irrigation for the non-irrigators?
10. How do you view the effect of irrigation on farmers' vulnerability to climate variability and adaptation to rainfall variability, drought and other natural calamities?

B) Farmers' interview guide for female household heads

1. How do you view the participation of female headed households in small scale irrigation in your locality?
2. Do you face any special challenge while you are working in irrigation compared to male headed households? If so, what are the challenges? Why some challenges are special for women in your locality?
3. In male headed households, do you think that women (wives) and men (husbands) share the benefit from irrigation equally? If no, why do you think?
4. In your community, who is the decision maker on financial affairs in male headed households (comparing wives and husbands)? What are the factor that control the responsibilities sharing between husbands and wives?
5. Have you ever been elected as member of the local level water users' association committee? If not, why?
6. Do you usually attend meetings scheduled by the water users' association committee? If not, why?
7. Do you think women are well represented in the WUAs committee? If no, why?
8. Do women participate equally with men in attending meetings and other collective actions needed in the WUAs? How? Why?
9. Is the existing SSI practices and technologies gender friendly? Why? How?
10. Do the irrigation water schedule suitable for you and other female household heads? If no, why?

11. Do all WUAs members participate in the planning, implementation, monitoring and evaluation of irrigation projects in your area? If no, why and how?
12. What do you suggest for future actions to be taken to improve the participation and benefits of women from small scale irrigation?

C) Interview guide for experts and bureau heads

1. How do you view the effect of irrigation on agricultural productivity? What is the role of irrigation on farmers' vulnerability to climate variability and their adaptation strategies to rainfall variability and drought considering irrigators and non-irrigators or using the before-after approach?
2. What looks like the trend in the development and expansion of smallholder irrigation in your locality? What are the main reasons that are contributing for the expansion of irrigation? Is irrigation relevant to your locality?
3. What are the factors that affect the participation of farmers in irrigation? Are the factors different for male household heads and female household heads, if any?
4. What is the dominant water conveyance and field water application system of the farmers? How do you view the smallholder irrigation practices based on the sustainability of water resources?
5. Do farmers in your locality adopted water saving irrigation techniques? If so, what are the techniques? Do you have any challenge to introduce water saving techniques? If any, what are the challenges?
6. What are the effects of irrigation on soil, farm land, pasture land, forest resources and biodiversity of your locality? Discuss positive and negative effects, if any?
7. Is there any conflict that happened among the community due to irrigation practices in your area? If so, what were the causes of the conflict? How the conflicts were solved?
8. How do you describe smallholder irrigation practices based on gender? Do men and women equally access and get benefited from irrigation agriculture in your locality? How and why?
9. How do you describe the benefits and costs of irrigation among the downstream and upstream farmers?
10. What do you recommend towards improving the contribution of irrigation for enhancing economic, social and environmental benefits in your locality?

D) Interview guide for WUAs committee chairperson

1. How do you view the participation of female headed households in small scale irrigation in your locality?
2. How many numbers do your WUAs committee has? What is there gender composition?
3. Do you think women are well represented in the WUAs committee? If no, why?
4. Do women participate equally with men in attending meetings and other collective actions needed in the WUAs? How? Why?
5. Is the existing SSI practices and technologies gender friendly? Why? How?
6. Who is the decision maker in managing financial affairs at the household level? Men/women/children? How? Why?

7. In male headed households, do you think that women (wives) and men (husbands) share the benefit from irrigation equally? If no, why do you think?
8. Do female headed households face any special challenge while they are working in irrigation compared to male headed households? If so, what are the challenges? Why some challenges are special for women in your locality?
9. Do all WUAs participate in the planning, implementation, monitoring and evaluation of irrigation projects in your area? How?
10. What do you suggest for future actions to be taken to improve the participation and benefits of women from small scale irrigation?

Appendix VII: Field pictures



Household interview with irrigation user farmer at Arata Chufa SSIS site (Source: own picture, 2017)



Household interview with irrigation user farmer at Bochesasa site (source: own picture, 2017)



Household interview with female irrigation user farmer at Dodicha site (source: own picture, 2017)



FGD with irrigation user and non-users at Dodicha SSIS (Source: Own picture, 2017)



Field visit on groundwater based SSIS at Bochessa site (Source: Own picture, 2017)



Soil and water sample collection Bochessa and Dodicha SSIS site



Soil and water laboratory salinity testing at Ethiopian Water Works and Supervision Laboratory center



Irrigation pond filled with Sediment at Arata Chufa SSIS (Source, own picture, 2017)

Appendix VIII: Correlation table of soil parameters

	pH-H2O (1:2.5)	pH-KCL (1:2.5)	EC (ms/cm) (1:2.5)	Exch. Na (meq/100gm of soil)	Exch.K (meq / 100 gm of soil)	Exch. Ca (meq / 100 gm of soil)	Exch. Mg (meq / 100 gm of soil)	CEC (meq / 100gm of soil)	Sum of Cations (meq/100gm of soil)	Exchangeable Sodium % (ESP)	ECsat. Ext. (ms/cm)	Na (meq/l)	K (meq/l)	Ca (meq/l)
pH-H2O (1:2.5)	100	0	0	0	0	0	0	0	0	0	0	0	0	0
pH-KCL (1:2.5)	99.9	100	0	0	0	0	0	0	0	0	0	0	0	0
EC (ms/cm)(1:2.5)	44.9	45.5	100	0	0	0	0	0	0	0	0	0	0	0
Exch. Na (meq / 100 gm of soil)	85.8	85.7	35.76	100	0	0	0	0	0	0	0	0	0	0
Exch. K (meq / 100 gm of soil)	43.4	44.5	17.65	72.41	100	0	0	0	0	0	0	0	0	0
Exch. Ca(meq/100gm of soil)	-27	-27	55.98	-43.45	-33.7	100	0	0	0	0	0	0	0	0
Exch. Mg (meq / 100 gm of soil)	-10	-11	62.58	-19.76	-25.7	75	100	0	0	0	0	0	0	0
CEC (meq / 100gm of soil)	-21	-21	52.71	-12.77	13.3	73	64	100	0	0	0	0	0	0
Sum of Cations (meq /100gm of soil)	17	18	82.67	13.78	17.9	81	75	78.8	100	0	0	0	0	0
Exchangeable Sodium % (ESP)	87.3	86.8	23.56	96.04	60.3	-54	-33	-37	-3.02	100	0	0	0	0
ECsat. Ext. (ms /cm)	71.8	73	65.88	76.57	51.7	-11	2	-4	33.45	74.43	100	0	0	0
Na (meq /l)-paste	79	79	54.3	90.7	59.9	-24	-10	-10	26.43	89.79	90.63	100	0	0
K (meq/l)	28.8	29	52.01	48.05	63.5	7.2	21	16	46.11	42.31	62.85	59.7	100	0
Ca (meq/l)	56.9	56.6	-29.5	68.38	50.9	-74	-67	-60.6	-42.26	78.89	41.94	59	20	10
Mg (meq/l)	58	57.8	-11.87	82.29	79.1	-64	-55	-34	-17.8	83	51.45	68	36.6	86
Sum of Cations	71	71	2.6	87.1	67.5	-61	-50	-43	-15.25	92.36	67.23	83	44.1	9
Bicarbonate (meq/l)	41	41	-33.24	45.177	36	-54	-62	-50.5	-35.7	58.31	21.27	40	19	8
Chloride (meq/l)	48	49	-3.57	79	81	-52	-43	-8	-4.62	73.1	50.58	68.8	33	7
Sulphate (meq/l)	77	77	28.21	90.36	60.3	-41	-24	-31	8.34	93.62	77.8	91	54	7
Sum of Anions	70.6	70.2	6.28	86.98	67	-52	-44	-36	-6.31	91.67	65.34	84	48.3	9
Sodium Adsorption Ratio (SAR)	42	42.4	86.73	38.98	20	37	40	35	62.64	31.548	61.22	63	51	-1

