Water Sharing Mechanisms, Crop Choice and Impact of Irrigation on Household Food Security and Poverty Reduction: The Case of Koga Irrigation Development Project in Northern Ethiopia

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Presented in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Development studies (Specialization in Rural Development)

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Declaration

This study, my original research work, has not been presented for a degree in any other university. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

The work was done under the guidance of Dr. Bamlaku Alamirew (PhD, a*ssoc. prof.*) at Addis Ababa University and Dr. Aseffa Seyoum (*PhD*) at BIOME Services PLC, Addis Ababa, Ethiopia.

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In my capacity as supervisor of the candidate's study, I certify that the above statements are true to the best of my knowledge.

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This is to certify that the thesis prepared by Koyachew Enkuahone entitled **"*Water Sharing Mechanism, Crop Choice and Impact of Irrigation on Food Security and Poverty Reduction: The Case of Koga Irrigation Development Project in Northern Ethiopia*"** and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in development studies (Specialization in Rural Development) compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

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External Examiner: ___________________________Signature _____________ Date ___________

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Chair of the Department or Graduate Program Coordinator

DEDICATION

I wholeheartedly dedicate this Dissertation to my dearest mother Yeshinesh Ayenew for her unreserved love and prayer. This work is also dedicated to all persons whose life philosophy regardless of the religion they followed is “***truth and humanity first.***”

Abstract

Agriculture remains the mainstay of the Ethiopian economy. However, the sector is highly affected by climate change induced extreme weather events. This leads to inconsistent and low agricultural production and productivity which exacerbates the food insecurity and poverty problems in rural Ethiopia. Cognizant of the facts, the government has been making interventions to augment otherwise low production and productivity. The Koga irrigation development project (KIDP) is one of such initiatives. However, due to physical, socio-economic and institutional challenges, the project has not reached its desired goals. The purpose of this study is thus to assess the water sharing mechanisms, crop choices and the impact of irrigation on household food security and poverty reduction in the KIDP. The data were collected from the household survey (395 households; 220 irrigators and 175 non-irrigators) drawn using multi-stage sampling techniques, FGDs, key informant interviews and field observations. Various econometric models, as well as descriptive analysis, were employed to analyze the data. The result of the study revealed that irrigation water in the KIDP was shared through poor mechanisms as compared to the standards for modern irrigation schemes water application system. Beneficiaries share water through a simple schedule set by the water committee which failed to consider details of factors. The distribution of water was not equally applied across irrigation reaches. Being influenced by combinations of socio-economic and institutional factors, households were mainly participating in regulation and controlling collective activities to manage the irrigation scheme. Irrigating households in the KIDP were predominantly cultivating cereal crops combined with both vegetables and cash crops. Length of crop maturity period, crop in-home utilization and crop marketability were the most determinant factors of farmers' crop choice decisions under irrigation farming. Irrigation has a statistically insignificant impact on the household's multidimensional food security, but it has a positive and significant impact on their annual income and multidimensional poverty reduction. Nonetheless, the impact was not evenly progressed across irrigation reaches within the system. Therefore, unless there is additional support to the poor, increasingly generated income in irrigation agriculture might not necessarily guarantee a household's multidimensional food security. Based on the conclusions drawn, the study recommends that the scheme needs to adopt modern technologies and scientific scheduling modalities for fair and equal water distribution throughout irrigation reaches. Farmers should be encouraged to participate equally in various collective irrigation management activities to ensure *system sustainability. To enhance irrigation returns at the study area, the government, experts and non-government organizations need to focus on the factors that affect farmers' crop choice decisions. Furthermore, the growing interest of policymakers in promoting irrigation should give first line attention in providing mechanisms of converting income into food security and targeting the right poor to enhance rural poverty reduction.*

Keywords*:* Irrigation, household, water sharing mechanism, farmer participation, collective management activities, crop choice, multidimensional food security, multidimensional poverty reduction.

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However, errors, omissions and other problems that exist in the study rest on me.

Koyachew Enkuahone Kassie

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Acronyms and Abbreviations

FAO	Food and Agricultural Organization
ATT	Average Treatment effect on the Treated
CPR	Common pool resource
CSI	Coping Strategies Index
FCS	Food Consumption Score
FGDs	Focus Group Discussions
FGT	Foster–Greer–Thorbecke
FIML	Full Information Maximum Likelihood
GDP	Gross Domestic Product
GFSI	Global Food Security Index
HDDS	Household Dietary Diversity Scale
HFIAS	Household Food Insecurity Access Scale
HH	Household
HHS	Household Hunger Scale
IMT	Irrigation management transfer
ITCZ	Intertropical Convergence Zone
KIDP	Koga Irrigation Development Project
MDGs	Millennium Development Goals
MFI	Multidimensional food security index
mha	Million hectares
MNL	multinomial logit
MPI	Multidimensional Poverty Index
NGO	Non-Governmental Organization
OPHI	Oxford Poverty and Human Development Initiative
PCA	Principal Component Analysis
PI	participation index
PIM	participatory irrigation management
PSM	Propensity Score Matching
rCSI	reduced Coping Strategies Index

SAFS	Self-Assessed Measure of Food Security
SPSS	Statistical Package for the Social Sciences
STATA	South Texas Art Therapy Association
TH	Transitional Heterogeneity
TU	Treatment effect on the Untreated
UNDP	United Nation Development Program
UNO	United Nation Organization
VIF	variance inflation factors
WIDE	Wellbeing and Illbeing Dynamics in Ethiopia

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Recent estimates indicated that more than 1,300 million people in the world are found under absolute poverty from which rural poverty takes the largest share (Alkire *et al.*, 2015). The FAO has reported that about 795 million people have been suffered from inadequate access to enough food and chronic undernourishment in the years 2014-2016. Particularly, poverty and food insecurity remain a persistent problem in many developing countries. For the last several decades, East Asia and Pacific, South Asia, and Sub-Saharan Africa have accounted for some 95 percent of global poverty(World Bank, 2014). It is highest in Ethiopia among Sub-Saharan countries (Alkire *et al.*, 2015). The most frequently mentioned drivers of such problems in the world in general and in Ethiopia, in particular, include population pressure, climate change and high agricultural dependency on variable rainfall (Bogale *et al.*, 2011; Regassa *et al.*, 2008; Turral *et al.*, 2011). Cognizant of the facts, countries give priorities for irrigation technology in the process of combating climate change and reducing agricultural rainfall dependency thereby improving the livelihood of beneficiary households (Gebregziabher & Namara, 2008; Omilola, 2009).

Historically, irrigation originated as a method for reducing climatic uncertainties in agriculture practices (Plusquellec, 2002). It is also a system for improving natural production and sustaining food supply by increasing the productivity of available land especially, in drought-prone areas of the world (Dowgert & Fresno, 2010). However, irrigation practice has not yet reached its optimum potential in the world. According to the 2009 FAO report, 311 million hectares (mha) in the world were potentially irrigable but only 84 percent was actually being irrigated (Renner, 2012). This covers 20% of the world's total cultivated land and provides 40% of the world's food supply, while the remaining 60% of food is supplied from 1,260 mha under rain-fed agriculture (World Commission on Dams, 2000).

As of 2010, the countries with the largest irrigated areas in the world were India (39 mha), China (19 mha), and the United States (17 mha) (Renner, 2012). The expansion of irrigation in India was coupled with availability and access to new technology which in turn has facilitated the intensification of cropping practices (Bhattarai *et al.*, 2001). In contrast, Ethiopia does not yet fully benefited from irrigation technologies (Awulachew *et al.*, 2010). Recent sources indicated that out of potentially cultivable land (30 to 70 mha), approximately 15 mha is currently cultivated from which irrigation schemes covering about 640,000-ha across the country (Awulachew *et al.*, 2010). This reveals that majority of the farmers in Ethiopia have limited access to irrigation agriculture which worsens the incidence of poverty and food insecurity in combination with increasing natural resource degradation.

Despite its slow expansion, irrigation remains vital for production improvements all over the world. One of the evidence is, for example, the positive growth rate record of cereal production in developing countries, particularly in sub-Saharan Africa (Chauvin *et al.*, 2012). Similarly, India, China, and Pakistan have achieved food self-sufficiency in the 1960s and the 1970s by using irrigation and the success of these countries is considered one of the significant achievements of the 20th century-unprecedented in the past (Bhattarai *et al.*, 2001). In addition, irrigated agriculture has a significant contribution to the value of agricultural products. For example, in 2007, in the United States, the average value of farm products sold by irrigated farms was 3.3 times the average value for non-irrigated farms (Dowgert & Fresno, 2010; Schaible & Aillery, 2012). A case study carried out by FAO in Ethiopia in 2001 has also confirmed that there was a marked value increment on irrigated farm products. Irrigation also contributes to the value of livestock and poultry products since animal forage and feed can be produced using irrigation.

Furthermore, irrigation has been playing an incommensurable role in widening the horizons of crop choice decisions to produce diversified types of crops. In irrigation agriculture households pursue different cropping strategies depending on their access to financial and human resources, level of knowledge and skills, and dependence on agriculture as a source of income (De Sousa *et al.*, 2017). Taking all the facts in mind, the Ethiopian government has been working on small and large dam nurtured irrigation project operations and expansions to improve agricultural productivity and production (Eguavoen & Tesfai, 2012).

During and after establishments, irrigation water management has been owned by different authorities; sometimes by the government and otherwise by the beneficiaries. Currently, most of developing countries have been transferring management of communal irrigation schemes from state to users because it is believed that schemes maintained better and their performances increased when farmers manage the schemes on their own (Muchara *et al.*, 2014).

However, irrigation development trends in the world show that the activity is not free from controversies. Many irrigation projects are performing poorly with respect to poor water distribution mechanisms. Salinization, soil erosion, flooding, fragmentation of landholdings, bad macro-economic policies, water losses, non-payment of water charge and neglecting of high-value crops are also associated with the low efficiency of irrigation schemes (Kirpich *et al.*, 1999). In general, the effective water sharing mechanisms, the power of farmers to decide on the type of cultivating crops and the actual contribution of irrigated agriculture to global food production, maintenance of food security and rural livelihoods are issues that are debated in the literature. Therefore, this study is intended to shade some light on irrigation water sharing modalities, factors affecting farmers' crop choices and the impacts of irrigation on rural household food security and poverty reduction.

1.2 Statement of the Research Problem

Agriculture remains the mainstay of the Ethiopian economy, as it does not only contribute to the largest share of gross domestic product (GDP), but it is also a key contributor to wealth creation, food security and poverty reduction (Gebre-Selassie & Bekele, 2012). It is contributing 41.4% of the country's GDP, 83.9% of the total exports, and 80% of all employment in the country (Matouš *et al.*, 2013). Agricultural production is the source of livelihood for eight out of ten Ethiopians, especially crop production is the core of Ethiopian agriculture and food economy (Namara *et al.*, 2008).

However, high dependency on variable rainfall and high susceptibility to climate change induced extreme weather shocks, such as drought and periodic floods has slowed down the productivity of the sector (Alemayehu *et al.*, 2013; Dawit & Balta, 2015; Turral *et al.*, 2011). Also, overgrazing, deforestation, high population density, poor infrastructure, and poor land and water management practices have led to massive soil degradation leading to low productivity (Bossio, 2005; Gebre-Selassie & Bekele, 2012). As a result, rural household food production is not consistently growing (Alemayehu *et al.*, 2013). The incidence of poverty and food insecurity is, thus, highly concentrated in rural areas which are the highest among sub-Saharan countries (Alkire *et al.*, 2015;

Beegle *et al.*, 2016). According to the assessment made in 2011, more than 30% of the Ethiopian population was living below the national poverty line where the share of rural poverty was highest (MoFED, 2012).

Therefore, raising agricultural production and productivity levels are considered essential aspects of improving household food security and reducing poverty in Ethiopia, both to ensure adequate food availability and to increase rural household incomes. Among others, using irrigation technology is deemed to be one of the solutions as it reduces the adverse impacts of climate change and agricultural rainfall dependency (Omilola, 2009). Also, it enhances the expansion of cultivable area and multiple time use of land in a year which, in turn, increases farm productivity (Asayehegn *et al.*, 2011; Ayele *et al.*, 2015). Particularly, in the smallholder sub-sector and in drought-prone areas, irrigation has significant importance for raising production and productivity at national and household levels that ensure food self-sufficiency (Dawit & Balta, 2015; Dowgert & Fresno, 2010). Furthermore, the changing climate and concerns over food security and poverty reduction are prompting a new look at the supply chain reliability of products derived from agriculture, and the potential role of crop choice to address climate and price risk (Huh & Lall, 2013). Irrigation, therefore, plays a vital role to address such issues because it widens the opportunity of crop choices.

Having this in mind, the Ethiopian government has been making interventions through the development of irrigation schemes to augment otherwise low production and productivity. Koga irrigation development project (KIDP) is one of such initiatives developed to ensure household food security and reduce rural poverty. The project has been established in the central highlands of Ethiopia in view of high population pressure, erosion hazard and declined per capita food production in the area (MacDonald, 2004). Since there were frequent years of droughts in which the small-scale farming has had trouble keeping up with the increasing population's food requirements the project was supposed to improve the formerly used rain-fed agriculture (Ministry of Water Resources, 2008). Furthermore, the dwellers in the area had been experiencing traditional irrigation agriculture by using the *Koga* river just before the establishment of the project. It was, therefore, believed that given such experiences, the establishment of the project would provide better relief for farmers to practice their agriculture under the changing climate. As a result, the foundation of the KIDP was laid dawn in 2008 and the construction was completed in 2012. By encompassing 7000ha of land, the major aim of the project is to address food security, poverty reduction, health, water and sanitation among smallholder farmers (Haileslassie *et al*, 2009).

However, only providing irrigation infrastructure to farm households does not mean household food insecurity and poverty are reducing. So as to actually make the poor farmers to maximize their profit, an enabling physical and socio-economic environment must be provided to them. In addition to access to institutional supports, the better achievement of the schemes depends on the appropriate working structures such as proper water sharing mechanism and participatory scheme management approach (Muchara *et al.*, 2014; Ostrom, 2010). It also depends on the crop choice decisions made by farmers in view of profit maximization (Kamiya & Ali, 2004). Inline of this, scholars noted a category of challenges that affect the contribution of irrigation schemes for food security and poverty reduction. These includes (1) improper irrigation water management and field water application (2) inadequate community involvement and consultation, and (3) inadequate knowledge on improved and diversified irrigation agronomic practices (Hagos *et al.*, 2009; Haile & Kasa, 2015; Makombe *et al.*, 2011).

In connection to this, due to poor water sharing practice, shortage of input supply, limited market linkages, political unrests, poor irrigation utilization skill of beneficiaries, low participation level of water users in management activities and other institutional challenges, the KIDP has not reached its desired goals. In addition, smallholder farmers lack making a decision to allocate their land among different crops with varying water requirements in view of enhancing production and addressing poverty and food insecurity.

Empirical studies on the issues of irrigation water management in general and specifically on irrigation water sharing mechanisms are very limited in the literature and have argued that inequitable irrigation water distribution observed in catchments is because of the application of inappropriate water sharing mechanisms (Li *et al.*, 2017; Mwadini, 2016). Some other studies are focused on farmers participation in irrigation scheme management activities and demonstrated how irrigation beneficiaries participate in collective management activities and what are the influencing factors for their varying degrees of participation (Arun *et al.*, 2012; Khalkheili & Zamani, 2009; Lin, 2003; Muchara *et al.*, 2014; Padmajani *et al.*, 2012).

There is ample literature that has studied farmers' crop choice decision aspects. However, several studies have focused on rain-fed agriculture. Only a few studies, for example, Abro (2012), Ayele *et al.* (2015) and Azam &Zoebisch (2009) have conducted under irrigation agriculture and have argued that factors such as crop marketability, water supply, input costs, farming experience, and policy decisions determine irrigators' crop choice decisions.

A plethora of studies have been done on irrigation impact of food security and poverty across different schemes in the world. Except some, such as Norton *et al.* (2014), (Pender *et al.*, 2000) and Hussain &Wijerathna (2004), most of the studies have confirmed that irrigation has a positive impact on household food security and poverty reduction (Awulachew *et al.*, 2008; Bacha *et al.*, 2011; Bhattarai & Narayanamoorthy, 2004; Gebregziabher & Namara, 2008, 2010; Mangisoni, 2008; Omilola, 2009). However, despite the recent few studies (Demeke *et al.*, 2011; Maxwell *et al.*, 2013; Wineman, 2016), most have employed a single (one-dimensional) index to measure food security and poverty.

Generally, empirical studies indicated that the literature regarding irrigation water sharing mechanisms is found scanty and also the schemes in Ethiopia are not assessed in this point of view. The documented empirical literature pertinent to the determinant factors of farmers' crop choice decision under irrigation is also found paucity. Furthermore, the literature indicates that there is no single common agreement among researchers on the impact of irrigation which varies based on agro-ecology, irrigation typology and applied technology. Moreover, the literature indicated that studies have employed a one-dimensional method of food security and poverty measurements which failed in capturing multiple dimensions because food security and poverty are multidimensional in their nature. As a result, this study is desired to measure them by applying multidimensional indices. Overall, the KIDP was not assessed on the glance of the issues raised by this research.

Therefore, to fulfill the literature, methodological and local knowledge gap, this research is intended to investigate water sharing mechanisms, determinants of beneficiaries' crop choice decision and the impact of irrigation on food security and poverty reduction in the KIDP, Northern Ethiopia.

Specifically, this study has addressed the following research questions:

- How is water shared among beneficiaries?
- How beneficiaries participate in irrigation management activities and what are the hindering factors for their participation?
- What are the determinant factors that influence farmers' crop choice decision under irrigating agriculture?
- Does agriculture under irrigation improve the food security of beneficiary households?
- Does irrigated agriculture reduce the poverty of participant households?

1.3 Objectives of the Study

1.3.1 General objective

The general objective of this research is to examine water sharing mechanisms, determinants of crop choice decision and the impact of the KIDP on household food security and poverty reduction.

1.3.2 Specific objectives

This study has designed to address the following specific objectives:

- To assess water sharing mechanisms applied in the KIDP and households' participation in collective irrigation management activities
- To explore the determinants of farmers' crop choice decision under irrigation agriculture
- To evaluate the impact of the KIDP on household food security
- To scrutinize the impact of the KIDP on household's poverty reduction

1.4 Significance of the Study

The study is worth undertaking for the following vital contributions. Following the gaps stipulated under the statement of the problem, the primary contribution of the study is to add the empirical knowledge about irrigation water sharing mechanisms, determinants of farmers' crop choice decision and the impact of irrigation in improving household food security and reducing poverty. The other main contribution of the study is to bring to the mind of policymakers the significance of the issues at hand in improving the rural poor through carefully thought-out recommendations presented at the end of the study. Based on the empirical evidences, the study delivers good policy implications on irrigation water application technologies, crop choice decisions under irrigation agriculture in view of enhancing food security and reducing poverty. In addition, it shows the gap that policy makers should have to account in the meantime of promoting irrigation for food security and poverty reduction. Furthermore, this study provides important policy insights and lessons for improving the current program of irrigation development in Ethiopia. Moreover, the findings of this study will be significant when they are used in designing better interventions in the future as existing irrigation schemes are rehabilitated and new ones are constructed. For those who show an interest of further research in the area, this paper can also be used as a spring-board.

1.5 Delimitation of the Study

In an attempt to address the above research objectives, the study has been delimited spatially and operationally. Due to time and budget constraints, the study is spatially delimited to the Koga irrigation development project. Also, it is not designed to see every aspect of this scheme. As a result, the scope of this study is delimited to the issue of water sharing mechanisms applied in the scheme, determinants of farmers' crop choice decision and the impact of the project on household's food security and poverty reduction. The sample of irrigator and non-irrigator villages was taken so as to delimit the research in the study population.

1.6 Structure of the Dissertation

The Dissertation is a monograph type which structured into eight independent chapters. The first chapter starts with an introduction which meant to provide the reader with a clear picture of the problem of the study in broad and in the context of the study area. Under this chapter, the objectives, research questions, significance of the study, limitation and delimitation of the study are presented. The second chapter continues with a critical review of related literatures under which theoretical and conceptual backgrounds of the problem and empirical evidences are discussed. Thirdly, the methodology of the study and description of the study area are comprehensively presented. In this section, data sources and data gathering techniques, procedure of sample size determination and the method of data analysis are described. The fourth chapter deals with the preliminary results and discussions of the study. In this chapter a clear introduction has been given on respondents' socio-economic and basic demographic characteristics. Fifthly, the result and finding of the first objective that is water sharing mechanisms practiced by beneficiary households in the *Koga* irrigation development project and farmers' participation in irrigation management activities is presented. The sixth chapter presents the major determinants of farmers' crop choice decision under irrigation agriculture. The next two subsequent objectives that is the impact of irrigation on household multidimensional food security and poverty reduction are thoroughly discussed under chapter seven. Here, the econometric model results are presented and interpreted. Finally, the fifth chapter concludes the Dissertation with carefully thought out conclusions of main findings, possible recommendations and potential areas for future research.

1.7 Ethical Considerations

Any research involving human or animal subjects has ethical implications. As a result, this study is bound to ethical issues in research that involve human subjects. The researcher first structured the necessary permission from authorities in the study woreda and kebeles to conduct the study after presenting a letter of cooperation written by Addis Ababa University, the center for rural development. The researcher then obtained the informed consent of the respondents after clearly informing them about the purpose of the study and the process of the household survey. The respondents were also informed that the interview starts when they are voluntary and they are also free to withdraw in the process at any time if they felt that they were being exploited or if the results of the study might hurt them. In addition, to ensure their safety during and after their involvement in the study, their privacy and confidentiality were kept with utmost care. In short, the study has followed and guided by the prominent principles of research ethics.

CHAPTER TWO

LITERATURE REVIEW OF THE STUDY

2.1 Introduction

Under this chapter, the review of related literature is briefly presented. The chapter looks at the concepts and definitions of food security, poverty, irrigation and crop choice. In addition, the relevant theoretical foundations for the issues under study are presented. In essence, the research identifies, evaluates and synthesizes the relevant literature particularly to the field of study. The case studies reviewed below are useful in developing and testing some of the maintained research questions. It illuminates how knowledge has evolved within the subject of study, highlighting what has already been done, what is generally accepted, what is emerging and what is the current state of thinking on the topic. In addition, the research has identified the gap and articulates how a particular research project could address the gaps. Based on the review of the literature, it formulates the conceptual framework of the study.

2.2 Definitions and Concepts

2.2.1 The concept of irrigation technology

Scholars broadly defined irrigation as the practice of artificially supplying and systematically applying additional water to the soil in order to enhance plant growth and to obtain higher or better production (Ali, 2010; Ayana & Awulachew, 2008; Sojka *et al.*, 2002). It is the controlled application of water for agriculture and/or horticulture and plays a protective role of insurance against the vagaries of rainfall & drought (http://shodhganga.inflibnet.ac.in/). Irrigation may be the single most strategically important intentional environmental modification (Sojka *et al.*, 2002).

Historically, irrigation has been a central feature of agriculture for over 5,000 years and is the product of many cultures. The archeological evidence shows that irrigation in farming starts about 6000 B.C. in the Middle East's Jordan Valley. It is also widely believed that it had been practiced in Egypt at about the same time. In the period following World War II, irrigation development has been rapidly expanded across the world. New irrigation systems such as center pivot and other sprinkler delivery systems were introduced in a few short decades between and immediately following the wars to revolutionize the ability to deliver water. Then huge government-sponsored irrigation programs were initiated in the 1930s, 40s and 50s in the U.S., Soviet Union, Australia, and Africa (Sojka *et al.*, 2002). Now a day, irrigation is continued practicing in advance by being a major determinant for realizing food security and poverty alleviation. Irrigation enhances agricultural production and improves the food supply, income of the rural population, opening employment opportunities for the poor, supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops (Ayana & Awulachew, 2008).

Irrigation Typology

Irrigation schemes have been classified into numerous typologies or classifications. However, the classification criteria in the literature vary significantly. Some countries use criteria of scheme formalization or technology utilization and others use areal coverage or capacity to irrigate. In rear cases, irrigation systems are also classified based on ownership as the state, private or public irrigation schemes.

For example, the irrigation system typologies in Ghana were classified based on the level of formalization (Namara *et al.*, 2011). Schemes divided into two broad groups; (1) the conventional systems and (2) the emerging systems. The conventional typologies are largely supply driven systems which initiated and developed by the Government of Ghana or various NGOs with the intention of attaining food security, domestic water supply, livestock watering, etc. This typology has been further classified into five systems, based on the source of fund and source of water. They are public surface irrigation, small reservoir-based communal irrigation, domestic wastewater and stormwater irrigation, recession agriculture or residual moisture irrigation and traditional shallow groundwater irrigation systems. The emerging irrigation systems are initiated and developed by private entrepreneurs and farmers, either autonomously or with little support from the government and/or NGOs.

Awulachew &Yilma (2008) made a practical classification of the Ethiopian irrigation schemes. The capacity of the scheme to irrigate plots is the criteria that have been used to classify. Accordingly, schemes are classified into the following typology. Small scale irrigation: this typology of irrigation can irrigate less than or equal to 200 hectares. Modern schemes and traditional schemes are categorized under this typology. Medium scale irrigation: these schemes cover exceeding 200 ha but less than 3,000 ha. Large scale irrigation: this type of irrigation scheme includes those irrigation systems which can irrigate exceeding 3,000ha of land. The latter two are mostly public schemes, owned and managed by the government, and in certain cases by large communities. Based on their classification, Koga irrigation scheme is, therefore, grouped under large scale irrigation project.

As per the report of Allen (1991), irrigation projects in the Indian context are classified into three typologies. The first one is the major project category which consists of huge surface water, storage reservoirs and flow diversion structures. The area envisaged to be covered under irrigation is of the order over 10,000 hectares. The medium project is the second typology. These are also surface water projects but with medium size storage and diversion structures with the area under irrigation between 10,000 ha and 2,000 ha. The third is a minor project under which below 2000 ha is proposed to be irrigated and the source of water is either groundwater or from wells or tube wells or surface water lifted by pumps or by gravity flow from tanks.

2.2.2 Why smallholders choose crops to grow?

The "poor-but-efficient" hypothesis set out by Schultz (1964) in his book "Transforming Traditional Agriculture" argues that smallholders are poor, but are generally efficient and rational decision makers in their allocation of agricultural resources to the production of crops. They decided to cultivate the type of crop through prioritization. The priorities might include producing high yield and marketable product or cultivating water shortage resistant and short time taking crop or aiming to increase soil fertility and etc. Though their priorities could be varying, their end goal seem to be risk aversion and profit maximization. The less income a farmer has, the more risk averse he will be, and the more risk averse a farmer is, the less likely he will be to invest more in his farm operation (Dercon & Christiaensen, 2011). There are also arguments that perhaps smallholders could not be necessarily rational in their crop choices because even when some crops are found to be more productive than others, the less productive crop is often chosen (Ubabukoh, 2016).

Several authors have outlined that farmers choose crops aiming to obtain optimal output from a given amount of inputs. For example, Van den Berg *et al.* (2007) explained that Chinese farmers select high-value vegetable crops and away from rice because they believe that it enables them to sustain a reasonable income level given present farm-size distributions. Hassan &Nhemachena (2008) indicated that in order to withstand climate change vulnerability in Africa, especially the summer warming risk, farm households are urged to use multiple cropping and integration of livestock rather than practicing only mono-cropping. Similarly, Abro &Sadaqat (2010) proved that diversification towards high value and labor-intensive crops could provide adequate income and employment to the farmers. Crop selection towards high-value crops indicated rural income growth and offered an opportunity to augment income, generated employment opportunities, and alleviated poverty. Birthal *et al.* (2013) concluded that agriculture diversification on fever of high-value crop choice can potentially increase farm incomes, especially in a country where demand for high-value food products had been increasing more quickly than that for staple crops. Husain *et al.* (2001) note that "the intensive monoculture of rice led to a displacement of land under low productive non-rice crops such as pulses, oilseeds, spices and vegetables, leading to erosion of crop diversity, thereby, endangering the sustainability of crop-based agricultural production system".

2.2.3 The concept of food security

Food security as a concept was originated in the mid-1970s during the discussions of international food problems at a time of global food crises. Since then, there is a substantive change in its definition and concept, encompassing issues related to the nature, quality, quantity and security of the food supply, causes, coping strategies as well as issues of food access (Clay, 2002; Tarasuk, 2001).

However, a commonly accepted definition of food security was given by the 1996 World food summit, but later it was refined in 2001 in the state of food insecurity. It stated that food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary food preferences for an active and healthy life (Babu *et al.*, 2014). However, the recent concept of food security has given more attention to households and individuals than its availability at international, national or regional levels. This is because increasing food production, supply and sufficiency at broader levels do not necessarily ensure the food security of individuals (D. Maxwell, 2001). According to FAO, food security on household level exists when all members of a household can be supplied with sufficient and adequate food, whether through their own production or buying of food.

In most cases, the measure of food security encompasses four pillars: availability, accessibility, utilization and stability. Food availability is determined by the physical quantities of food that are produced, stored, processed, distributed and exchanged. Food access could mean physical access to food in the market or economic access to food at the household level, and food utilization relates to how food consumed is translated into nutritional and health benefits to the individuals (Babu *et al.*, 2014). On the other hand, even though it is not conceptually detached from the former, recent food security models such as global food security index reduced the pillars into three: affordability, availability, and quality and safety (EIU, 2013).

Therefore, this study adopts the definition which entails that a household is food insecure when it has no adequate physical, social or economic access to food and when a household is unable to afford the available food in the market. This could be determined by using pre-defined food security threshold.

2.2.4 The concept of poverty

Poverty is a widely used and multidimensional social phenomenon in all countries of the world, but its definition is often contested. The literature on poverty is full of controversies; possibly most of these controversies arise from opinion differences and misunderstandings between definition and measurement (Pantazis *et al.*, 2006). As a result, poverty has no clear-cut common definition.

In the World Summit conference for social development in Copenhagen in 1995, the UN has broadly discussed the concept of poverty and it was defined by considering various issues such as lack of income and productive resources, hunger and malnutrition, lack of access to education and health services, increased morbidity and mortality, homelessness and inadequate housing, unsafe environments and social discrimination and exclusion. It was also characterized by lack of participation in decision-making and in civil, social and cultural life (United, 1995).

Researchers commonly agreed upon a definition that “poverty is having an insufficient command of resources over time”. In economics poverty has broadly defined by two research traditions; welfarist and non-welfarist. The welfarists believe that the preference (utility) of individuals has a great deal in determining poverty (Ravallion, 1994). They understand welfare as utility derived from the personal satisfaction of a certain state of being and these utilities are both additive and comparable across different persons. In this mono-dimensional case, per capita income or expenditure is used as a proxy for the possible set of utilities. Poverty is then defined as the state when per capita income or expenditure is not sufficient to meet a normative reference level of utility (money) that every person must have to not starve, or fulfill basic consumption needs, or have a relatively acceptable lifestyle (Neubourg *et al.*, 2010). On the other hand, the non-welfarists understand poverty based on certain achievements such as being adequately nourished, clothed and sheltered, as well as intrinsically multidimensional. They believe that instead of pursuing a universally applicable proxy for all states of welfare, it seeks to directly measure the outcomes achieved on certain predefined notions of needs (Neubourg *et al.*, 2010; Ravallion, 1994). Analogously, Peter Townsend (1979) has also thought that poverty should understand objectively rather than subjectively. In his argument individuals, families and groups in the population said to be in poverty when they lack the resources to obtain the types of diet, participate in the activities and have the living conditions and amenities which are customary, or at least widely encouraged or approved, in the society to which they belong (Townsend, 1979). In order to understand the dynamics of poverty, one can also draw the attention on the notions of 'capabilities' and 'entitlements' (Sen, 2000). Sen's work focuses on the idea that income shortfalls are the main attribute of poverty. He emphasizes the importance of the bundle of assets or endowments held by the poor, as well as the nature of the claims attached to them (Namara *et al.*, 2008).

While the criticisms of the income approach to welfare have always existed, it was not until the innovation of multidimensional poverty measurements such as the work of OPHI and UNDP in 2010. An emerging body of research has argued that income and consumption expenditure measures only cover certain dimensions of poverty and lack the ability to indicate the actual meaning of poverty in the lives of those people who experience it(Senaratna Sellamuttu *et al.*, 2014). To date, the literature on multidimensional poverty measurements is vibrant and marked by recurrent innovations. It is an aggregation technique and building a composite index to define poverty rather than using a single proxy.

Generally, the definitions discussed above clearly show that poverty does not mean an absolute basket of goods, but it is defined in terms of the minimum acceptable standard of living applicable to a person's/household's own society. Accordingly, researchers defined poverty based on the context of the target population and the way they measured it. This study also focuses on analyzing poverty identified through the multidimensional index. Though it is scientifically impossible to determine an accurate, uniquely valid poverty line or a financial threshold (Atkinson *et al.*, 2004), the poor are, therefore, those who do not have enough resources to put them above the defined adequate minimum threshold.

2.3 Review of Theoretical Literature

This part deals with the review of historical and theoretical literature relevant for the issues under investigation. Earlier theories of common pool resource management in Ostrom's view, agricultural decision making, opportunity theory and theory of aspiration are found relevant to the study and they are critically reviewed.

2.3.1 Common pool resource management: Ostrom's view

Common pool resource (CPR) is characterized by subtractability and joint use by a group of appropriators (Ostrom, 1990). Irrigation is one of CPRs which is jointly used by irrigation beneficiaries (Muchara *et al.*, 2014). However, the administrative ownership of this resource is seen affecting its sustainability. Despite the huge government investments in the establishment and refurbishment, irrigation schemes that face collapse soon after their operation are not few (Cousins, 2013). Some scholars in the "tragedy of the commons" argue that state control (ownership) on CPRs is important to prevent their destruction, while others recommend privatizing those resources to resolve the problem. But, Ostrom and her associates argued that since neither the state nor the market is uniformly successful in enabling individuals to sustain long-term productive use of irrigation resources (Gardner *et al.*, 1990), many countries have implemented irrigation management transfer(IMT) and participatory irrigation management (PIM) policies. The rationale is to improve the maintenance of irrigation facilities and irrigation service, enhance the productivity of irrigated land and water, promote a culture of self-reliance among farmers and assure the sustainability of the system.

Despite others, the philosophy of collective action is popularly applied to manage irrigation schemes. Collective action is conceptually explained that a group of farmers sharing resources is supposed to cooperate in order to maximize benefits from the resource (Olson, 1965). Ostrom in her book of “governing the commons”, has addressed how CPRs could be managed successfully by organizing collective action without falling prey to the "tragedy of the commons”. According to her argument, problems in managing CPRs arise when the rational individual determines that he/she will still have access to the resource even if he/she does not fully contribute to its maintenance (the "free rider" problem) which fall the resource into ruin. To resolve this problem, she suggested an approach of designing durable cooperative institutions that are organized and governed by the resource users. She emphasized that farmers have survived over the centuries due to their evolved knowledge of how to engineer complex irrigation systems including dams, tunnels and water diversion structures of varying size and complexity. However, these systems cannot work well without agreed-upon rules for allocating water as well as allocating responsibilities for providing the needed labor, materials, and money to build the systems in the first place and maintain them over time (Ostrom, 2008).

Generally, for the success of the institutions in sustaining the CPRs and gaining the compliance of generation after generation of appropriators to the rules in use, Ostrom has identified eight similar design principles. The first principle is demarcation of clearly defined boundaries to identify the members of the households who have rights to withdraw resource units from CPRs as well as the physical boundaries of the CPR. The second is congruence between appropriation and provision rules and local conditions, requires appropriation rules (regarding the time, place, acceptable technology, and quantity of CPR allocated) to be specific to the characteristics of the actual resource; similarly, the rules governing the contribution required of each appropriator must mirror local conditions. Third, collective-choice arrangements allow participation by all affected individuals in deciding on the appropriation and provision rules. Fourth, either the appropriators themselves or persons accountable to the appropriators are responsible for monitoring compliance with collective decisions. Fifth, sanctions should be graduated to reflect the severity, frequency, and context of the violation. Sixth, low-cost and readily available conflict-resolution mechanisms must exist to mediate conflicts among appropriators and between appropriators and officials. Seventh, users must have recognition of their own rights to organize institutions. Finally, nested enterprises, i.e., sets of rules established within a hierarchy of appropriator institutions, must be established for common-pool resources that are within larger resource systems and political jurisdictions.

2.3.2 Agricultural decision making in view of crop choices

Crop choice decision is central to any crop farming agriculture. Before cropping commences, the farmer has to make important decisions which profoundly affect the subsequent operational management. A farmer must consider profitability, adaptability to changing conditions, resistance to disease, and the requirement for specific technologies during growth or harvesting of crops. Agricultural decision-making models have made different arguments regarding the operational requirements of decisions in agriculture follow from this.

Farm business can operate effectively if the people running the business have clearly defined the business and their personal goals. Farmers decide to farm because they want to farm, because they enjoy the lifestyle and because they hold deep-seated values and beliefs around living and working on a property that has often been in the family for generations (Greig, 2009). Studies of farmers' economic rationality using Cobb-Douglas production functions have argued that farmers act as profit maximizers within their technological and institutional constraints (Vieth & Suppapanya, 1996). But this approach has been criticized because profit maximization tests of economic efficiency in agriculture are mis-specified if farmers are making decisions in the presence of risk. Contrarily, others argue that agricultural decision models not including risk considerations may overestimate output levels of risky crops and fail to recognize the importance of diversification in traditional agricultural production systems (Vieth & Suppapanya, 1996). Empirical applications of behavioral models and theoretical considerations indicate the importance of incorporating risk into the analysis of farmers' decision making. Environmental, market and policy factors will always exist in agricultural decision making and it is important to consider them in agricultural decision making (Schaffnit-Chatterjee *et al.*, 2010). However, there is no clear consensus regarding the importance of the factors which influence agricultural decision making in general and crop choice decision in particular.

One can discern two distinct world trends in agricultural decision-making that is at the farm and higher levels. Depending on their political, economic and social structure, countries have experienced different agricultural decisions. For example, in market economy countries, the basic decisions are taken by individual farmers and the market helps to coordinate them. Many of these countries confine the individual decisions of farmers by advisory or regulatory actions at the local, market and national levels. In socialist countries, on the other hand, agricultural decisions are taken by the state and individual farms do not have much choice of their own inputs, outputs and techniques (Samar, 1977).

Furthermore, agricultural decision-making is no longer confined to national authorities. Forces of international supply and demand situations and environmental considerations are regulating national actions. Especially, commercialized agriculture is increasingly influenced by international trade and finance. The national authorities in their decision-making for agriculture have to consider whether the existing international arrangements are the most appropriate for objectives like "security" or "development" and, if not, what kind of change needs to be made and how (Hassan & Nhemachena, 2008).

At the farm level, decision-making is basically the function of the household or the enterprise manager. They set simple and clear objective like, say, maximizing net financial return and then their decision would be to harvest crops that enable to attain their objective. Greig (2009) and Rahman (2008) showed that a marked difference in crop choice decision is found between commercial and subsistence farmers. In the case of subsistence type of agriculture, what farmers prefer to eat influences their planting decisions and institutional and social factors are often more significant than economic factors. However, for commercialized farmers, the economic capabilities of the crop appeared significantly more influential and the decisions are often of better quality and more innovative. This indicates that the decision-making structure will vary considerably not only between different socio-economic systems but also between different stages of economic development within the same system. Therefore, Freedom to take decisions at the farm level with adequate research and information facilities will help to promote innovation and raise production. As a result, a scientific study of crop choice decision making in irrigation agriculture at the farm levels has become important.

2.3.3 Theoretical underpinnings of food security and poverty reduction

2.3.3.1 The opportunity theory

In development economics and other social sciences, there are various theories that argue about the nature of food security and poverty and inequalities. Influential literature advocated mostly by economists is the ‘opportunity’ theory. This thought was originally inspired by political philosophers during the 1970s and 1980s. Beginning with John Rawls (1971), a number of authors revived the idea by progressively moving the “demand for equality” from the realm of individual achievements to the space of opportunities. Economists soon followed the thought of political philosophers. After influential contributions by John Roemer and Marc Fleurbaey in the 1990s, a substantial literature has emerged which considers personal responsibility and opportunities to evaluate the opportunity-equalizing effects of social and economic policies. The focus of the economists was to examine what part of the inequality observed in a particular country is due to unequal opportunities, rather than to differences in individual efforts or luck. Inequality of opportunity has been then analyzed in different spheres of human life and for different domains of public policy, ranging from income distribution to anti-poverty and/or food insecurity strategies.

In economics, the central idea of the opportunity theory reveals that welfare inequality observed in a particular country is due to unequal/limited opportunities, rather than to differences in individual efforts or luck (Ferreira & Gignoux, 2011). It is viewed that economic inequality is neither all bad nor all good and the gaps have arisen from limited opportunities rather than the application of different levels of efforts (Roemer & Trannoy, 2015). The kinds of opportunities that are detrimental to welfare outcomes include, for example, access to good schools, financial markets, irrigation technologies, health centers or access to information technologies (Bourguignon *et al.*, 2007). There is a widespread normative view that inequality of such opportunities matters for outcome inequality. This has commanded considerable attention in the analysis of poverty and food security inequality. The typical stance taken is that food insecure and poor people lack access to those opportunities which are defined as legitimate avenues for food security and poverty reduction (Cernkovich & Giordano, 1979). Therefore, opportunity deprivations lower economic achievement levels which, in turn, lead to variations in such outcome levels. Hence, regardless of individual efforts, limited access to irrigation technology may be strongly associated with the food security and poverty level of irrigator and non-irrigator households at the study area.

2.3.3.2 A theory of aspiration

An influential literature in studying the origins of "poverty and food insecurity traps" argues that persistent poverty and food insecurity is imposed by constraints that are external to the individual such as institutional or governmental failures, coordination problems and malnutrition (Bardhan, 1997; Da Rin & Hellmann, 2002). However, in a different approach, economists widely advocated that besides to extrinsic circumstances, food insecurity and poverty trap is perpetuated by intrinsic factors such as aspirations and beliefs. In the theory of 'aspirations', economists believe that poverty has a close and brutal association with a failure of aspirations (Ray, 2006). Guney *et al.* (2011) stated that "our aspirations shape our choices and influence countless aspects of the economic part of our daily lives." Therefore, the capacity to aspire is a key ingredient in any notion of empowerment (Dalton *et al.*, 2016; Ray, 2006) which includes both the ability to set goals and the knowledge of how to achieve them (Appadurai, 2004; Dalton *et al.*, 2016). Contrary to this, poor people lack the capacity to aspire, contest and alter the conditions of their own poverty and food insecurity. Lack of aspirations, in turn, self-limiting mental shortcuts and restricts the future minds to those of necessity, reinforcing and perpetuating the cycle of food insecurity and poverty (Dalton *et al.*, 2016; Tanguy *et al.*, 2014). Expand the poor's aspirational horizon by means of programs which provide the poor to develop capabilities is, therefore, a possible way out of these traps.

The assumptions of 'limited opportunity' and 'aspirations failure' theories seem consistent with the findings of various food security and poverty researches in the literature which are discussed in the next sections. The findings, in most cases, revealed that the proportion of food insecure and poor households in non-irrigating agriculture remains high. Also, regardless of access to irrigation, food insecurity and poverty stays significant. This could be either due to limited irrigation opportunities or failure of aspirations in the society which may restrict them to underinvest against food insecurity and poverty. The focus of the present research has been to show the association of these thoughts to the explanation of food security and poverty impact of irrigation.

2.4 Review of Empirical Studies

2.4.1 Irrigation water sharing mechanisms

The existing literature on irrigation water sharing mechanism and field water application are based on empirical research, which uses primary or secondary data sources, but they are very few in number. One of the studies that attempt to deal with irrigation water sharing mechanisms and conflicts among irrigation beneficiaries is Haile *et al.* (2003). He found that there was an equal distribution of irrigation water within the command area of the investigated site. He argued this probability depends on the location, level of the command area along the flood river and the water sharing rules in place. In the line of this, Svubure *et al.* (2010) justified that small and medium floods benefit the upstream fields whereas large floods benefit downstream fields. As a result, conflicts which remain a critical factor to maintain and rehabilitate the system have occurred between upstream and downstream farmers; and also, between the irrigators and the water authorities. To solve such problems and ensure system sustainability as well as to enhance productivity, Haile *et al*. (2003) strongly argued that meaningful stakeholder participation, institutional support, and water allocation and distribution rules have vital roles.

Dukes *et al.* (2015) wrote a research-based guideline entitled "principles and practices of irrigation management for vegetables." It discusses that appropriate irrigation scheduling and matching irrigation amounts with the water holding capacity of the effective root zone helps to minimize the incidence of excess leaching. Irrigation requirements are determined by crop water requirements, the characteristics of the irrigation system, management practices, and the soil characteristics in the irrigated area. It is stressed that establishment of irrigation practices should include wider issues such as irrigation system type and capacity, climate demand, type of crop and crops growth characteristics, and field soil texture and hydraulic characteristics so that users can optimize production.

2.4.2 Determinants of households' participation in irrigation management

The empirical evidences on households' participation in collective irrigation management activities in the literature are done at different locations with different methodologies, but are inadequate. Starting from the recent ones, Muchara *et al.* (2014) has studied on collective action and households participation in irrigation water management in South Africa. The conclusion of this study indicates that the success or failure of small-holder irrigation schemes depends on user participation in management activities. Therefore, an understanding of the determinants of farmer participation in collective activities forms the basis to improve the management of communal irrigation schemes. According to their findings, low farmer literacy level and shortage of irrigation water were confirmed to be significant determinants of farmer participation. Hence, strengthening of local water management systems and institutional policies that ensure maximum benefits were suggested to encourage farmer participation. Analogously, using the cross-section survey data on the activities of irrigators' associations in the Philippines, Fujiie *et al.* (2005) identified the underlying factors in the success and failure of farmers' organizing collective actions for maintenance and operation of gravity irrigation systems. It is found that collective action is difficult to organize where: (a) water supply is uniformly abundant, (b) water supply is greatly different between upper and lower streams, (c) population density is low, (d) the ratio of non-farm households is high, and (e) the history of irrigated farming is short. It is suggested that these difficulties can be overcome with adequate supports of state agencies to promote community-level cooperation.

2.4.3 Determinants of farmers' crop choice decision

Crop choice is dependent upon many factors which influence or limit the freedom of choice and which are beyond the control of the farmer. Crop choice decision requirements under climate change agriculture receive wide interest among food policy researchers. As a result, varieties of factors that influence decision making on crop selection in different research locations have been presented by several studies. These factors are here reviewed by grouped them into physical factors, economic factors, personal views and characteristics of the farmer, and policy-related factors. Although this classification is arguably arbitrary in nature, owing to the presence of much overlap within each group, the overall aim was to ease the presentation and to gauge the importance of each group in previous studies. These are discussed in the following sections.

First, in the study of agricultural decision making, the literature considers various physical factors such as soil quality, the relief of the land, rainfall pattern, temperature and the availability of water. For example, Pender *et al.* (2006) provide evidence that rainfall pattern, temperature, land quality, land management practices and altitude influence crop choices in East African highlands. Rahman

(2008) in his study of determinants underlying the probability of adopting a diversified cropping system and/or modern rice technology in Bangladesh found that the availability of irrigation was the single most important determinant of adopting modern rice technology. A study carried out by Ayele *et al.* (2015) has a similar finding with Rahman (2008) that states access to irrigation highly determines crop selection. The finding revealed that farmers who grew only cereals were totally non-irrigation users whereas vegetables like tomato, head cabbage, onions and '*khat*' cash crop were very common for irrigation users. Greig (2009) and Abro (2012) have analyzed the key factors of crop choice in Tanzania and determinants of crop diversification towards high-value crops in Pakistan, respectively. In their analysis, it is indicated that the primary factors of crop selection such as vegetables and fruits were seasonality, irrigation water and rainfall. However, it should be noted that these researches were conducted in an area heavily reliant on high-value crop cultivation. Moreover, Rahman (2008) argued development of the rural infrastructure was found essential factor as this would not only improve technical efficiency but might also synergistically promote diversification by opening up opportunities for technology diffusion, marketing, storage and resource supplies. Besides, by analyzing household data from villages in North Eastern Ethiopia, Nuru &Seebens (2008) found that length of roads to the market, proximity to urban centers and access to the road along with other factors determine the crop choice in favor of the production of high-value crops. Crop choices further significantly predict levels of per capita income across villages where the farthest with no access to the road are the poorest. Overall, a level of debate is apparent in the literature as to the importance of physical factors in the decision-making process.

Second, several researchers deemed economic factors as fundamental. Ayele *et al.* (2015) in the study "determinants of farmers' crop choices on irrigation agriculture in southern Ethiopia", found that economic factors such as expenditures on agro-chemicals, fertilizer, seed and market distance were significant determinants of crop choices. Total expenditures on agro-chemicals such as herbicide and pesticide were significant for cereals-pulse-vegetables that indicate for a 1-birr additional cost on agro-chemicals results in decreasing the choice of these crops. Income strategy was also found a determinant factor to choose cereals with pulse and vegetables (Pender *et al.*, 2006). According to Rahman (2008), farm asset, as well as the share of non-agricultural income, are significant to adopt a diversified cropping system. Certain economic factors such as crop marketability, the price of the seed and potential profit regarded by farmers as important are also proved to be further influential (Greig, 2009). Moreover, it is concluded that per-capita income, off-farm income, non-farm income and access to farm machineries were identified as crucial determinants of crop choice in a fever to cultivate high-value crops (Abro, 2012; Ashfaq *et al.*, 2008). Ubabukoh (2016) has also found that access to free inputs and the use of seeds from the previous growing season are some of the important economic determinants of crop choice.

Third, numerous studies have considered the personal views and characteristics of the farmer, and policy-related factors in the analysis of crop selection decision making. Research has been undertaken on the experience of the farmer, age, education level, gender as well as on the influence of others on decision making in crop choice. Ayele *et al.* (2015), for instance, found that male-headed, educated and old aged farmers were most likely choosing high value crops like cereals with vegetables and '*khat*'. Consistently, Pender *et al.* (2006) stated that education level, gender, and tenure status of households significantly determines crop choices in East African Highlands. Besides, Ashfaq *et al.* (2008) confirmed that farming experience of respondents was one of the main factors affecting crop diversification and crop selection.

In addition to the aforementioned personal characteristics, land management practices and policy related factors such as irrigation technical assistance, extension service provision and the availability and use permission of fertilizers and pesticides were deemed detrimental (Greig, 2009). The delivery of extension services to smallholder farms', suggests that extension provision should prove important in the decision-making process underlying crop choice (World Bank, 2018). Access to information as well as the capacity to understand the technical aspects and profitability related to different crops also influences crop choice decisions (Rahman, 2008). According to Greig (2009), a significant difference in decision making among subsistence and commercial farmers was found. This is because subsistence farmers encouraged placing greater emphasis on the taste of the crop, whereas commercial farmers predictably more influenced by the market.

Within each category, a general lack of consensus is apparently observed regarding the importance of the factors which influence crop choice decision. Nonetheless, it is widely argued that the low utilization of the irrigation potential has affected farmers' crop choice and their productivity. It is also indicated as crop choice analysis is found to be very important for increasing farm productivity.

2.4.4 Irrigation impact on food security

Adoption of irrigation technologies and its consequences on food security continue to receive wide interest in the agriculture sector and food policy researchers in the world. Case studies undertaken by various researchers highlighted that irrigation has played significant roles in improving food security. Among the existing literature on irrigation and its impact on food security, a case study undertaken by Nkhata (2014) in Malawi is one of the recent shreds of evidences. The study examines the impact of irrigation on household food security using endogenous switching regression and propensity score matching methods. Per-capita caloric intake per day was used to measure food security. Accordingly, the finding revealed that irrigating farmers had improved levels of caloric intake over farmers that did not participate in the irrigation scheme. Traditionally marginalized groups (female-headed households, the youth, and low income households) were also attaining higher income than what they could have earned if they did not irrigate. Christine *et al.* (2008) have also evaluated the impact of the modern *Hare* river irrigation scheme on household food security and on the lifestyle of the population in Ethiopia. The study was a type of descriptive analysis based on food security pillars; access to food, availability of food, utilization of food and the overall factor of food stability. It was found that, in association with the construction of the modern irrigation, the community could improve the livelihood and food situation through the introduction of infrastructures such as agricultural office, health center, drinking water points, school, and electricity. Farmers could adopt new cash crops and it helps them to earn a higher income. But, the change from food crop to cash crop farming leads to less food crop production in the area which forced households to be dependent on the local market to purchase food crops. Analogously, a study undertaken by Tesfaye *et al.* (2008) has identified the impact of small-scale irrigation on household food security in Ada Liben district of Ethiopia. They conclude that small-scale irrigation is one of the viable solutions to guarantee household food security, but it could not totally eliminate the problem of food insecurity within the community. Access to reliable irrigation water enabled households to grow crops more than once a year which leads to increased productivity and greater income generated from farming which is accompanied by improvements in food security.

Gebregziabher (2008) has made a comparative analysis on farm production between irrigation and rainfall-based areas of *Tigray*, Ethiopia and found that the rain-fed areas produced subsistence crops and encountered a chronic food deficit. To the contrary, irrigation-based areas produced cash crops with surplus production due to doubling or tripling effects of irrigation that, in turn, enhances their food security. A study carried out by Nugusse &Speelman (2012-2013) assessed the condition of food security in small scale irrigation in Northern Ethiopia. The propensity score matching estimated that the mean annual income, consumption expenditure and asset accumulation for irrigators was higher than that of the non-irrigators. It was highlighted that solely access to irrigation may not always provide positive outcomes so that government and other organizations should give attention to strengthening the local institutions and expand social and physical services in areas. Using similar methodology with Nugusse &Speelman (2012-2013), Alemu &Bosena (2017) assessed the impact of small-scale irrigation on farm households' food security in North *Wollo* Zone of Amhara region, Ethiopia. The finding revealed that the intervention in small scale irrigation caused a significant mean difference between irrigator and non-irrigator groups in terms of daily calorie intake and household consumption expenditure per adult equivalent. The PSM confirmed that participation in small scale irrigation increased daily caloric intake and household consumption expenditure by over non-participant households. A time series (1992-2004) study conducted in the Arab countries indicated that irrigation enabled farm households to grow multiple crops two to four times a year. It also enabled them to expand their cultivated area, increase farm yields and increase household incomes thereby enhance their level of food security (Singh *et al.*, 2009).

In a different methodological approach, Parvin &Rahman (2009) examined the growth of the irrigated area and its impact on food grain production during the last three decades. Linear and exponential growth model were applied and found that rapid expansion of the irrigated area was attributed to the adoption of various technologies, for example, the conventional irrigation methods were replaced by modern methods. In association with the increment of irrigated area, cropping intensity was increased and contributed to increase the total rice production. As a result, the higher productivity of rice has helped the nation to meet food requirements in Bangladesh. Asiribo (2009) has assessed the income generating potential of irrigation farming and its implication to reduce poverty and hunger and to achieve the MDGs in Nigeria. The result of the study showed that irrigation farming is a profitable venture. Irrigation farming was found to be capable of alleviating poverty and hunger among farming households. Hence, irrigation farming can be one of the instruments to achieve the MDG of reducing poverty.

2.4.5 The impact of irrigation on poverty

Irrigation technology and its consequences on poverty reduction continue to receive wide interest of the agriculture sector and poverty policy researchers in the world. In recent years, it has been increasingly realized that poverty is a multidimensional concept, extending from monetary values to non-monetary dimensions and includes other livelihood dimensions. Hence, in conducting research on the poverty-irrigation linkage, researchers followed different methodologies to measure poverty. While non-monetary dimensions are important to measure poverty, most empirical works on poverty measurement are based on monetary values. Even in estimating poverty using monetary measures, one may have a choice between using income or consumption or yield as the indicator of well-being. Therefore, for ease of presentation, this study has classified the existing literature into the following themes based on the employed indicators; these are researches using income indicator, consumption expenditure indicator and productivity or yield indicator as a proxy to measure poverty.

2.4.5.1 The impact of irrigation on poverty reduction using income indicator

Among the existing literature on irrigation and its impact on poverty reduction which are done by using income as a proxy to measure poverty, most of the estimations are based on the FGT model. These types of literature face a problem to control sample selection bias. Case studies undertaken by Meliko &Oni (2011), Bacha *et al.* (2011), Namara *et al.* (2008) and Senaratna Sellamuttu *et al.* (2014) are some of the examples which highlighted the positive impacts of irrigation on poverty by using income proxy and FGT model. Meliko &Oni (2011) found that poverty incidence, depth and severity were higher among non-irrigation households in South Africa. Similarly, based on descriptive statistics, the FGT poverty indices, and Heckman's selectivity model methods of data analysis, Bacha *et al.* (2011) has found that the incidence, depth, and severity of poverty were significantly lower among those farm households with access to irrigation in the Ambo district of western Ethiopia. They indicated that regardless of access to irrigation, the proportion of poor people in the area is alarmingly high, indicating the deep-rooted and critical situation of poverty in rural Ethiopia. Namara *et al.* (2008) have also examined the impact of small-scale irrigation on rural poverty and inequality in Ethiopia. The study was based on an extensive data set generated form 11 small-scale irrigation schemes. Besides to the FGT, multivariate analysis was used and the finding revealed that poverty incidence was significantly lower among households with a higher irrigated area. Even if accesses to irrigation moves up the mean income, farmers have different capacity in making better use of the available irrigation water and therefore irrigation widens the income gap. Relatively with a different approach, Senaratna Sellamuttu *et al.* (2014) has used income proxy through livelihood choices and estimate from a two-stage income regression model. The result shows that irrigation access has a positive effect on income through livelihood choices in Sri Lanka.

Despite the studies that confined themselves on FGT, there are some researches which employ propensity score matching and switching regression models. These types of literature controlling for sample selection bias and are methodologically rigorous. Among them, one of the studies that attempt to deal with irrigation poverty linkages is a study conducted by Nkhata (2014) in Malawi. The study used endogenous switching regression and propensity score matching models to examine the impact of irrigation on poverty and to assess the impact with those growing one irrigated crop versus growing two crops for traditionally marginalized groups (female-headed households, the youth, and low-income households), respectively. He found that irrigation had a positive impact on annual agricultural income and the impact was different among the irrigators, with those cultivating both rice and maize irrigation earning more agricultural income than their counterparts growing rice only. Traditionally marginalized groups were also attaining higher income than what they could have earned if they did not irrigate. Analogously, Gebregziabher &Namara (2008) have attempted to evaluate the impact of small scale irrigation on poverty in Tigray, Ethiopia. The study used propensity score matching with a data set generated from 613 sampled households representing different agro-ecological zones and irrigation typologies. The average income of irrigating households was found above the regional average, whereas it was 50 percent less than the regional average for non-irrigating households. Both Nkhata (2014) and Gebregziabher &Namara (2008) argued that significant income improvement is accompanied by poverty reduction among farmers with access to irrigation in the study area.

Furthermore, using a quite different methodology, Fitsum *et al.* (2009) have assessed the importance of irrigated agriculture to the Ethiopian economy by capturing the direct net benefit contribution of irrigation to the national economy. They used “with minus without” irrigation approach, adjusted for changes in farm type and scale. It was argued that the net gross margin from irrigation is more than twice higher than the gross margin from rain-fed agriculture. The bulk of the contribution to the national economy comes from the smallholder managed irrigation schemes, most importantly from the traditional schemes. However, the contribution of irrigation to national income is found still very small.

2.4.5.2 The impact of irrigation on poverty reduction via expenditure and yield/productivity indicators

Hussain &Wijerathna (2004) undertake comparative assessments on 26 different irrigation systems and analyze their contribution to poverty alleviation in developing Asia. The analysis was based on measuring expenditure and on primary household-level data. It was found that, while irrigation has a contribution to poverty alleviation, the magnitude of antipoverty impacts varies greatly across systems and depends on a range of factors. These include size and equity in land holdings, equity in water distribution with proper maintenance, improved cultivation technology, cropping patterns, and level of crop diversification supported by market infrastructure to facilitate marketing of inputs and outputs. Therefore, the antipoverty impacts of irrigation decrease as one or more of these conditions do not hold.

Among others, the work of Bhattarai &Narayanamoorthy (2004) have received a good deal of attention who has made a macro level analysis on the impact of irrigation on agricultural growth and poverty alleviation in India. In their review of empirical studies, they confirmed that some of the recent aggregate level studies have proved the positive impact of irrigation on poverty reduction. However, they assured that no straightforward relationship has been shown between irrigation and poverty alleviation; and the impact of irrigation on poverty alleviation depends on several other intermediate factors. Thus, they feel that an improved understanding of the structure of the impact of various factors and quantification of marginal impacts of each of the factor inputs on poverty measures is important. As a result, they quantified the incremental impact of irrigation and other factor inputs on the growth of total factor productivity and its implications on poverty alleviation. Finally, the weighted least square regression results of the study show that the marginal impact of irrigation on the growth of productivity of all inputs is positive and significant. Among all the variables selected for analyzing the poverty measures in this study, irrigation has the strongest influence in explaining the reduction in poverty.

Despite others, a study carried out by Pender *et al.* (2000) is one of the studies which attempts to indicate the possibilities that irrigation might not directly improve poverty unless accompanied by other complementary interventions. Using yield estimation method of measurement, Pender *et al.* (2000) have argued that although irrigation development was found to contribute to some livelihood strategies, it did not lead farmers to adopt improved technologies and hence yields or welfare indicators were not increased as expected. Many farmers continue to use traditional technologies even when irrigation is available which limiting the productivity impact of irrigation and hence poverty reduction is not improved. These results are not conclusive but suggest that making more researches on the impacts of irrigation investments is fundamental to increase productivity in the field. Consistently with Pender *et al.* (2000), Jin *et al.* (2002) and Shenggen *et al.* (2000) have found a negative and/or weak relationship between irrigation and agricultural productivity implying negative or no impact on household income and poverty reduction at large.

2.5 Synthesis of Empirical Studies

Generally, this research reviewed empirical evidences regarding water sharing mechanism, crop choice and impact of irrigation on household food security and poverty reduction which founds useful in developing and testing the maintained research questions.

The studies which empirically examined irrigation water sharing mechanisms and determinants of crop choice decision under irrigation agriculture appeared to be very scanty. As a result, there remain limitations to synthesize the findings. Nonetheless, few of the reviewed cases explicitly reveal that lack of appropriate water application technology and unequal water distribution are depicted to be critical challenges in the performance of irrigation schemes. Active participation of beneficiary households in irrigation management activities is found to be key for the effectiveness and sustainability of the system. Crop choice decision under irrigation agriculture is made based on varying factors. The nature of these factors also varies across countries and schemes so that the literature lacks to provide a general conclusion rather than to the specific irrigation scheme.

The studies relate to the impact of irrigation on household outcomes such as food security and poverty reduction in the literature is seemingly diverse. Regression analysis and mono-dimensional food security and/or poverty measurement remain the most commonly adopted research methodology. Food security and poverty are not measured in a sense of multidimensionality rather they are estimated through the one-dimensional index which is either calorie intake, consumption expenditure or income. Inline of this, several studies put aside the problem of sample selection bias rather than employing a controlling methodology. The most conclusive results of the reviewed studies revealed that irrigation has positive impact on food security and poverty reduction. On the other hand, there is a wide argument on its net benefit for the poor that is, unless additional support is provided for the poor, only access to irrigation might not necessarily assure food security and poverty reduction. So, lack of consensus among researchers regarding the linkages between irrigation and poverty reduction is apparently observed.

Furthermore, up to this effort, there was no study conducted in the KIDP on the issue raised by this research.

Therefore, this research aims to make the following contributions in the literature. The first is fill the literature gap on water sharing mechanisms and crop choice decision under irrigation agriculture. The second is methodological that is controlling sample selection bias by employing propensity score matching and endogenous switching methods. Third, unlike others, the study measures food security and poverty by employing a more comprehensive methodology that is multidimensional indices. Fourthly, this study contributes local knowledge to the study area by evaluating the *Koga* irrigation scheme which is not yet evaluated.

2.6 Conceptual Framework

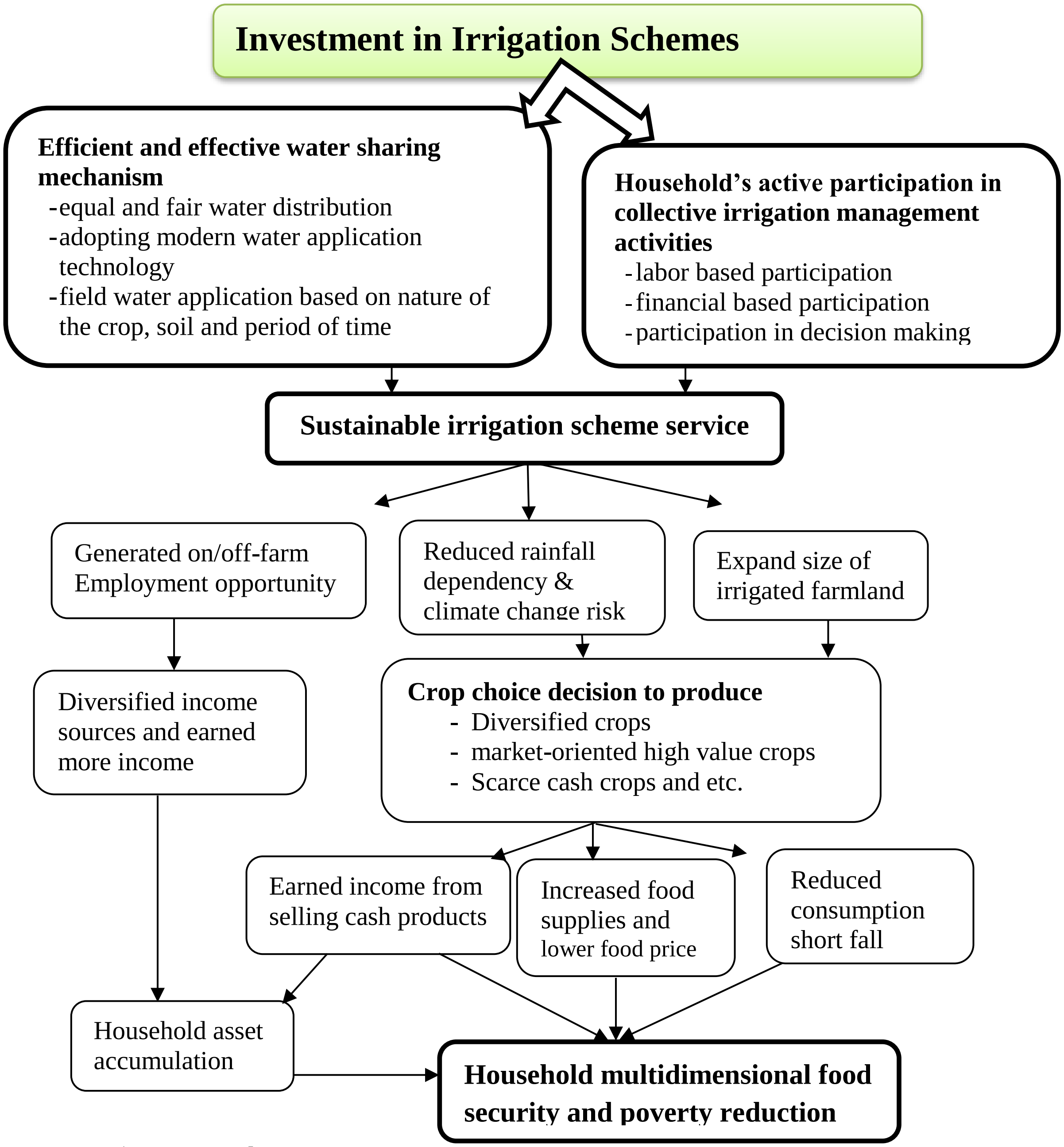
Based on the thorough review of the literature, the conceptual framework for the study is developed and depicted below (Figure 1) showing the linkages of irrigation water sharing mechanism, crop choice decision and food security and poverty reduction.

Agriculture in Ethiopia is vulnerable to climate change induced extreme weather events such as erratic rainfall and periodic drought, and accordingly, the government has given great attention to small- and large-scale irrigation agriculture as a means to ensure food security and alleviate poverty (Awulachew *et al.*, 2007). The conceptual model for this study, therefore, combines several critical variables to show how investment in irrigation projects link to food security and poverty reduction. As a vital resource in agriculture, the researcher hypothesizes that investment in irrigation water service contributes to many productive and livelihood activities. These contributions would be real when the service is sustainable. Studies show that efficient and effective water sharing mechanism and active participation of beneficiaries in collective scheme management activities are vital to providing a sustainable service. The framework indicates sustainable irrigation schemes can relieve farmers from high rainfall dependency and climate change risks and also increases irrigated farmland. It also generates employment opportunities which diversify the source of household's income and increase accumulating assets. Investment in irrigation creates on/non-farm employment opportunities; increases consumption expenditure and accumulating assets (Dawit & Balta, 2015).

Use of sustainable water service and year-round production in irrigated farmland encourages smallholders to shift from subsistence crops to produce diversified and high-value market-oriented crops as well as scarce cash crops, which in turn enable people to earn income from selling cash crops, increase food supply and lower food price, and reduce consumption shortfall. Reliable irrigation increases land productivity and crop yields that also enables to diversify into non-conventional and market-oriented products (high-value crops, vegetables and fruits (Eshetu *et al.*, 2010).

The positive effect of irrigation on household's income, asset accumulation and crop production is ultimately translated to household's multidimensional food security and poverty reduction. Sustainable irrigation service can reduce poverty by raising yields and production, lowering the risk of crop failure, and generating higher and year-round farm and non-farm employment for the poor(George *et al.*, 2015). However, the achievements of such broad goals are dependent on several factors such as water sharing methods, the participation level of beneficiary households in management activities and the type of crops chosen to be cultivated. It is assumed that the effectiveness of irrigation water sharing mechanism and management practice influences the activities to be done to enhance the sustainability of the system's service without which it is impossible to think about improved agricultural outcomes. Consistently, the crops chosen in agricultural practice are key determinants in the process of food security and poverty reduction. Therefore, in irrigation projects, a set-up of water sharing mechanism and households' participation in management activities for system sustainability and proper crop choice in considering the cost and benefits could be ultimately leading to household's multidimensional food security and poverty reduction.

Figure 1: Conceptual framework of the study



Source: Author's own draw

CHAPTER THREE

DESCRIPTION OF THE STUDY AREA AND RESEARCH METHODOLOGY

3.1 Introduction

The third chapter explains the methodological steps applied in this study. First, it gives a detail description of the study area. Then, the chapter sets out the research design and approach established for the study. It further explains the sampling procedures used to draw a representative sample size of the study population. Finally, the chapter describes the source of data, the tools and procedures of data collection, and the method of data processing and analyzing.

3.2 Description of the Study Area

3.2.1 Mecha Woreda[1]

Mecha woreda is one of the thirteen *woredas* in West *Gojjam* administrative *Zone*, Amhara regional state. It is located 34 km south-west of Bahir Dar town, the capital of Amhara Region and 526 km far from Addis Ababa. According to *Mecha woreda* administrative office (2017), the *woreda* administers 50 *kebeles*[2] with an estimated total population of 400,000. The *woreda* is well known for its flat topography and the altitude ranges from 1,800 to 2,500 meters above sea level with '*Dega*' and '*Woyina Dega'* agro-climatic zones. The mean annual rainfall in the *woreda* varies from 1,000mm-2,000mm. From the total area of the *woreda* (156,027 ha), nearly half, 72,178 ha is cultivated area. The land covered by water bodies' accounts 1,386 ha.

Agriculture and trade are the main livelihood activities in the *woreda*. Particularly, the subsistence level mixed farming is practiced in all parts of the *woreda*. The main crops grown in the area include maize, teff, finger millet, wheat, barley, chickpea, beans, Niger seed and cabbage. In the livestock sub-sector, cattle are dominant and large numbers of poultry, sheep and goats are kept.

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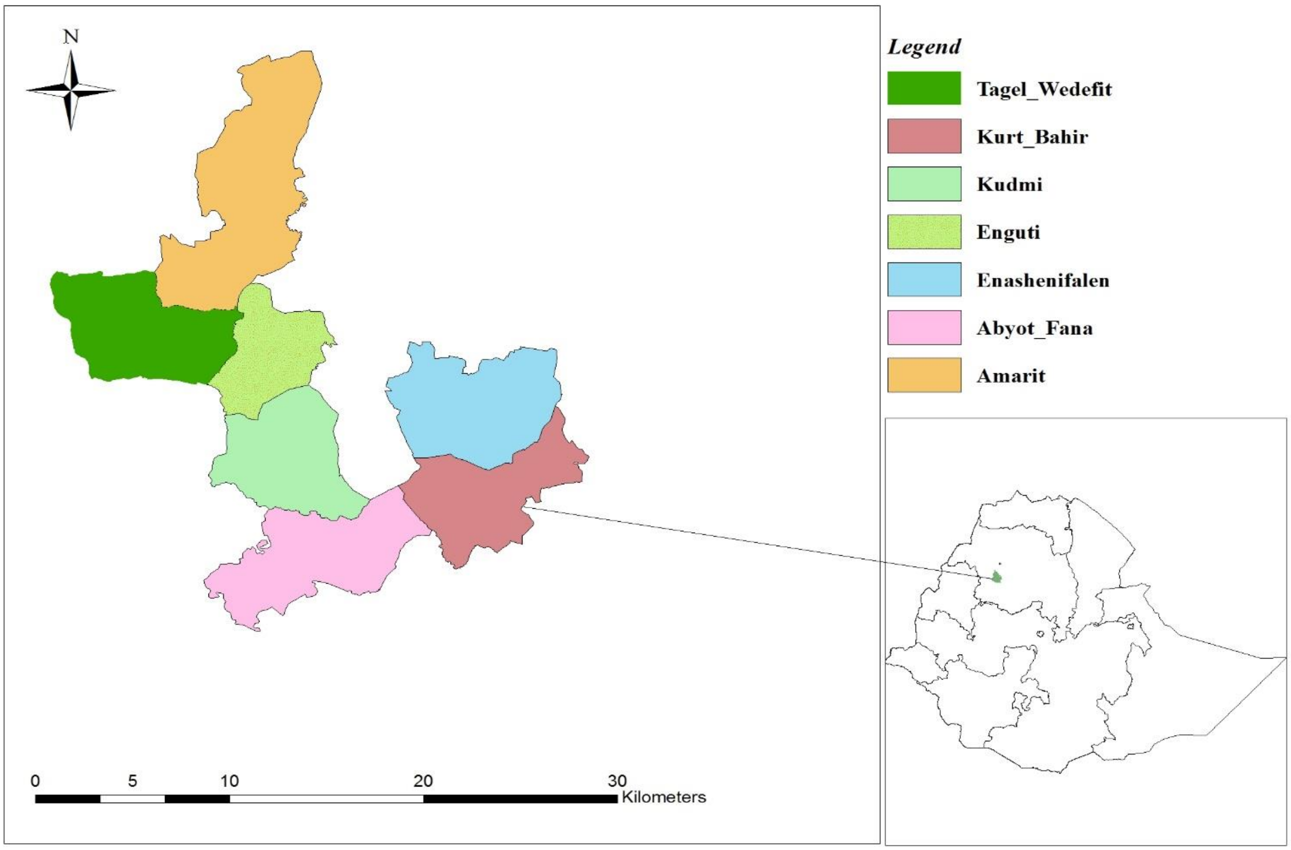
[1] *Woreda* is a division of Administration that administers a population up to 400 thousand.

[2] *Kebele* is the smallest administrative unit (administrative neighborhood units) of Ethiopia similar to a ward or peasant association

Oxen, cows, heifers, bulls, calves, chickens, goats and sheep are found in numbers in most households (Bahir Dar University, 2014).

Figure 2: Map of the study sites in *Mecha* woreda, Ethiopia



Source: author's own sketch using CSA's GIS data 2006.

3.2.2 The Koga Irrigation Development Project

The Koga irrigation and watershed management project (later renamed as "*Koga* irrigation development project") is one of the large-scale modern irrigation projects in Ethiopia (MacDonald, 2004). The project area was first surveyed and plan to establish the irrigation scheme by the *Derg* regime in the 1980's (Eriksson, 2012). The current government has resumed the plan and started the construction in October 2004 and completed in 2012. In collaboration with the Ethiopian government, the cost of the project was covered by African development bank (Eriksson, 2012). Since there were frequent years of droughts in which the small-scale farming has had trouble keeping up with the increasing population's food requirements the project was supposed to improve the formerly used rain-fed agriculture by allowing two crop seasons thereby reducing poverty and enhance food security (Ministry of Water Resources, 2008). The *Koga* Project is unique in Ethiopia because, in addition to basic irrigation development activities, it integrates forestry, livestock, soil management, water and sanitation.

3.2.2.1 Location and climate of the project area

The KIDP is found in *Mecha Woreda*, 7kms away from *Merawi*, the seat of the *woreda* and 526kms far from Addis Ababa, the capital of Ethiopia. The project is situated at the head of the Blue Nile basin within Lake Tana Watershed at 11^{o} 10' N to 11^{o} 25' N latitude and 37^{o} 02' E to 37^{o} 17' E longitude (Haileslassie *et al.*, 2009) under '*Woyina Dega*' agro-climate zone (Beyene, 2012).The area is subject to the Intertropical Convergence Zone (ITCZ), northern trade winds and the southern monsoon (UNESCO, 2004) cited in(Eriksson, 2012). Thus, it suffers from a dry period, called '*Bega'*, which begins in December and lasts until the end of May. There is a rainy period, called '*Kiremt'*, which begins from June/July and ends in September/October (Eriksson, 2012). The area has a mean annual rainfall of 1560 mm and a mean daily temperature between 16 and 20^{o}C (McCartney & Awulachew, 2006).

3.2.2.2 Structure of water delivery in the scheme

The KIDP irrigates 7004 ha land within a 22,000-ha catchment area. The project is classified into two parts; upper catchment and lower catchment. The upper catchment is the dam's watershed area whereas the lower catchment is the irrigation command area (Koga irrigation development project office, 2017).

According to the secondary data obtained from the KIDP office, the *koga* irrigation development project consists of various structures used for delivering water from the main dam to the farm fields (see the details in Table 1). The Project has two dams, called main and saddle dam. Both are made of semi-homogeneous earth fill with comprehensive filter and drainage system. The saddle dam is the smaller of the two with an embankment length of 1162 meters and a maximum height above the riverbed of 9 m. The main dam has 1730-meter length and 21-meter height and it has 83.1 million m^3 water impound capacity (Figure 3). There are also 11 night storage reservoirs which are used to store water at night when the smaller canals discharge is down (Eriksson, 2012) (Figure 4). The dam has one concrete lined main canal which runs over 19.7kms and delivers water to all command areas for 24-hour periods during times of irrigation. It starts at the dam outlet and has a length of 19.7 km.

Table 1:The command area and water delivery structures in KIDP

Block name	**Area (ha)**	**Secondary Canal**		**Tertiary Canal**		**Quaternary Canal**		**Tertiary drainage channel**	
		No	Length (Km)	No	Length (Km)	No	Length (Km)	No	Length (km)
Kudmi	373	1	0.875	7	9.0	31	47.9	3	4.6
Chihona	617	1	3.756	9	14.5	47	68.5	6	15.7
Ambo mesk	812	1	7.186	15	12.4	54	95.6	10	20.9
Adebera	803	1	2.505	15	13.1	53	90	5	4.4
Lasi	484	1	0.779	5	8.8	31	59.2	5	12.2
Enguti	393	1	4.472	3	7.3	26	44.7	4	13.4
Tagel wedefit	616	1	2.875	11	8.8	41	75.1	8	9.7
Bered	468	1	2.641	6	8.0	30	52.8	3	6.3
Andinet	497	1	0.868	4	6.5	33	46.1	4	7.9
Amarit	290	1	5.530	4	5.6	19	27.1	2	4.4
Tekeldib	864	1	2.841	9	12.1	53	91.4	11	19.6
Teleta	787	1	2.841	7	11.1	51	84.6	6	11.9
Total	7004	12	42.382	95	117.2	469	783	67	131

Source: Koga irrigation development project office, 2017.

As shown in the above table, the whole command area is divided into twelve blocks, but the size varies from 300-900 ha. Each block has one secondary canal having the same lining system as the main canal (i.e., 12 secondary canals in total) that delivers water for 12 hours from the main canal. The secondary canals are also used to distribute water from the night storage reservoirs.

The blocks are irrigated by tertiary canals which take off from a secondary canal. There are 95 tertiary canals and they deliver water to irrigate areas larger than 80-ha. The quaternary canals are 469 in number and they have a total length of 783kms and irrigate 8-16 ha. Unlike secondary and tertiary canals, they are completely unlined and earthen but are equipped with drop structures, cross regulators and off takes. There are also 67 tertiary drainage channels which have 131 km length and are used to remove water from the command areas (KIDP office, 2017).

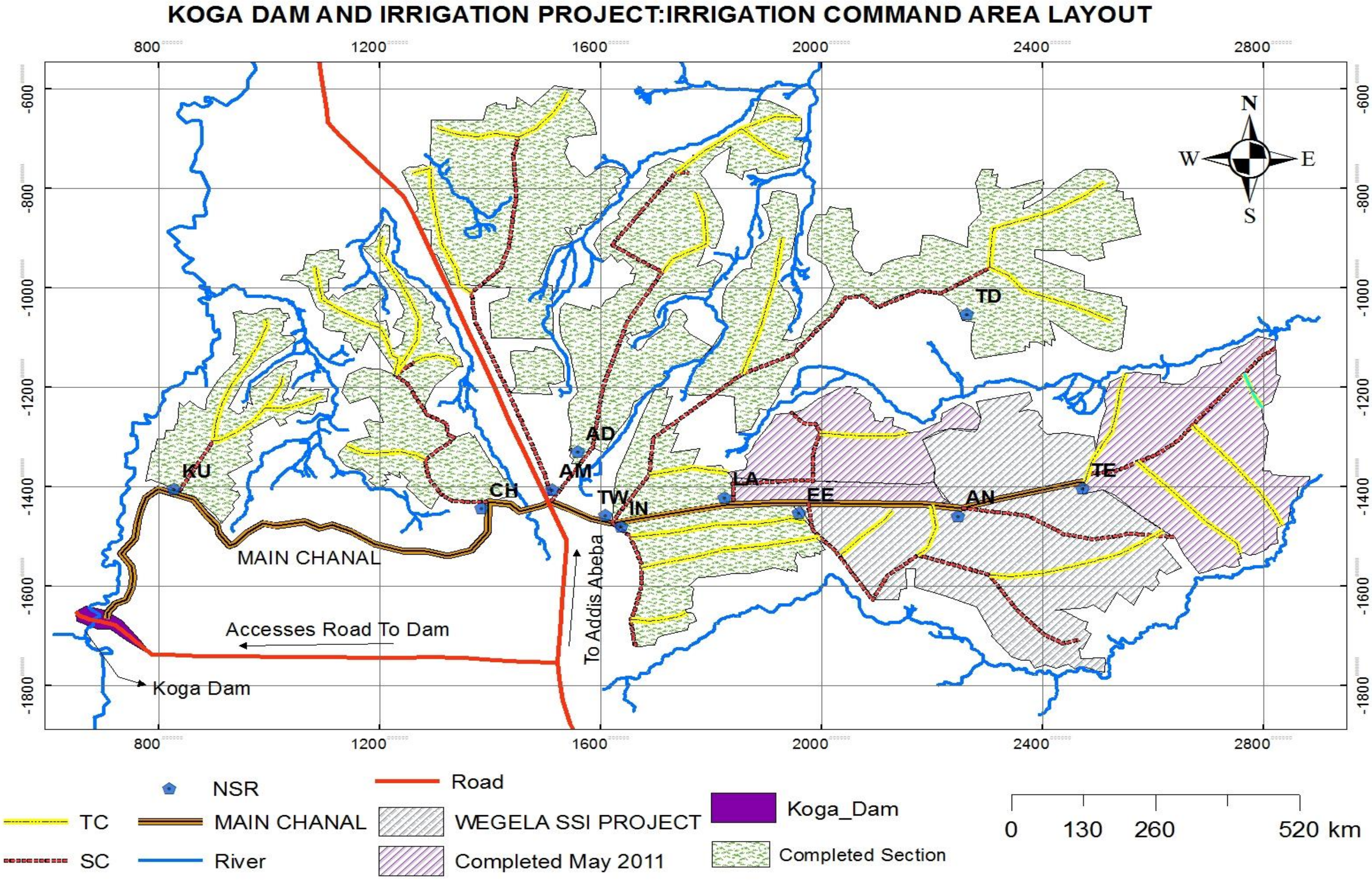
Figure 3: The main dam of the Koga irrigation development project

Source: Own field observation

3.2.2.3 Demography

The project command area encompassed 9 rural *kebeles* with about 14,000 households (Eriksson, 2012) in which 10031 households are irrigation beneficiaries (Koga irrigation development project office, 2017). The urban population of *Merawi* and *Wetet Abbay*, with estimated an population of 15,000 (a number which probably has increased by now) is also benefited directly and indirectly from increased economic activities from the project. Majority of these households in and around the project vicinity are dependent on farming for their livelihoods (McCartney & Awulachew, 2006). The main cultivated crops in the area are wheat, teff, maize, potato, shallot, pepper, garlic, onion, tomato and cabbage (Haileslassie *et al.*, 2009).

Figure 4: The Koga irrigation development project site map



Source: Taken from the KIDP office, 2017

3.3 Research Design and Approach of the Study

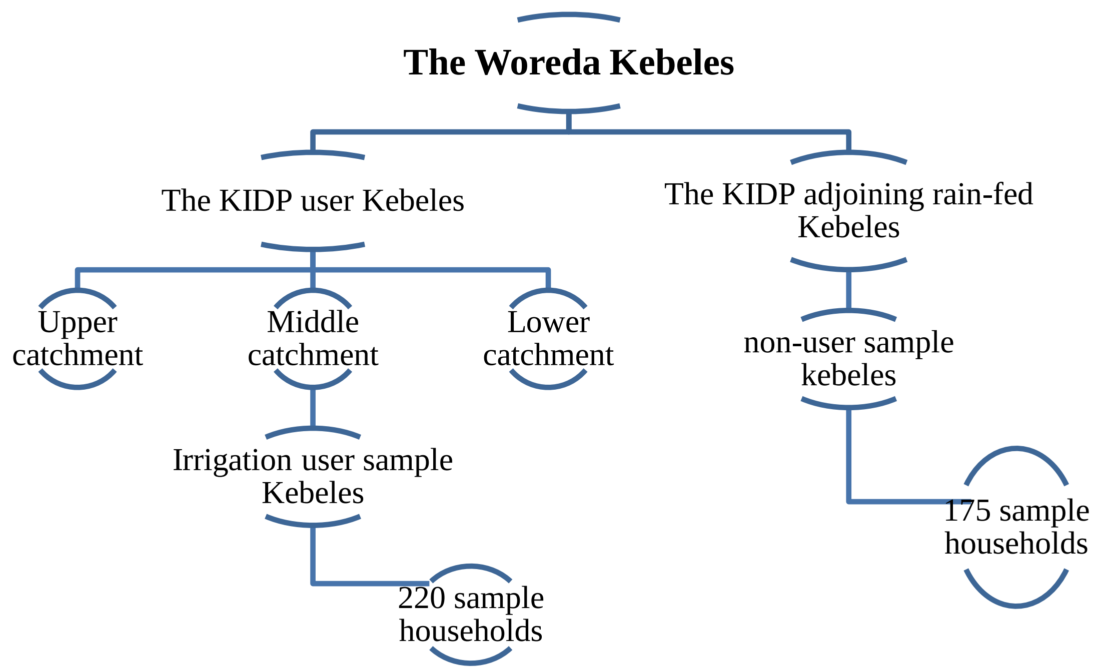
The KIDP area is one of the areas that have been influenced by poverty and food insecurity due to population pressure, erosion and climate change. The area has experienced a marked decline in per capita food production prior to the project (MacDonald, 2004). To overcome such problems, the KIDP project was launched. Therefore, this study has been designed to explore whether improvements come in associated with the project. Besides to this, the study was aimed to assess the water sharing system and crop choice determinants in the scheme because the project has not been studied since it is a newly established one.

So as to address the research objectives, the study follows a mixed (Pragmatic) research approach which focuses on the "what" and "how" of the research problem. Pragmatic paradigm is characterized as the paradigm having consequences of actions, being problem centered, pluralistic, real world practice orientated and using mixed models. Therefore, since this research is a cause and consequence type, mixed approach (pragmatic paradigm) is more appropriate to apply than other paradigms. This study also uses a cross-sectional study design because it is carried out over a short period to estimate the prevalence of the livelihood outcomes for a given population.

3.4 Population and Sampling Procedure

The sample population for this study was selected from irrigated and non-irrigated adjoining areas using a multi-stage sampling technique (Figure 5). The first stage involved the identification of *Koga* irrigation beneficiary *kebeles* by consulting with *Koga* irrigation development project head office. As a result, a total of 9 beneficiary *kebeles* were identified. In the second stage, these *kebeles* were purposively divided into three strata (i.e., upper, middle and lower catchment areas). Accordingly, proportional to their size, four sample *kebeles* were randomly selected from the three strata. In stage three, seven adjoining rain-fed *kebeles* were purposively identified based on agro-ecological similarity, distance closeness, agricultural practice during the rain-fed time, the land potential to produce, and cultural practices with irrigating *kebeles*. And then, three of them were randomly selected. The logic behind this is to examine the impact of irrigation on household food security and poverty by comparing irrigation users with that of non-irrigation users. In the final stage, following Yamane (1967) cited by Israel (1992), a total of 395[3] sample households were selected using random sampling technique in which 220 are irrigators and 175 are non-irrigators. At this stage, given the household number difference between *kebeles*, proportional sampling method was used to select the sample. The distribution of total households and sample sizes of households across *kebeles* are shown in Annex 1 and Annex 2. Furthermore, two focus group discussions with 8 participants in each group were conducted for the purpose of validating econometric results. The FGD participants were composed of male, female, adult and elder farmers. Note that for the purpose of preventing spillover effects, households registred as non-users within irrigating *kebeles* were exempted from the sampling frame because it is assumed that the spillover effect among them is higher than adjoining *kebele* dwellers.

Figure 5: Sampling framework



[3] $n = \frac{N}{1+N(e)^2}$, Where: n= Sample size, N=population size, e=level of precision
N= Total number of HHs in user and adjoining non-user *kebeles* (i.e., 24,890 HHs (13,922 users + 10,968 non-user))
e=95% confidence interval or 0.05 precision level

3.5 Data Sources and Methods of Data Collection

The study used both primary and secondary data sources. The primary sources were the household survey, focus group discussions, key informant interviews and field observations. The interviewer administered household survey questionnaire data were collected from the selected sample households and covered various issues: household demographic composition, social organization, land holding, crop production, livestock tending, asset ownership, household feed, irrigation water sharing systems, household participation in irrigation management, household crop choice factors, income from sale of crop products, livestock and labor and agricultural input expenditure. The FGDs were also held with irrigator and non-irrigator households to crosscheck the consistency of econometric findings and increase the validity of the results. The main concern was to ascertain whether there is food security and poverty difference among irrigator and non-irrigator groups and to overview the extent to which the project has affected households' food security and poverty status. Farming households' opinions about their source of income, money allocation, and their awareness on food security and poverty were assessed. The primary data through key informant interview were gathered from *Koga* irrigation development project office and *Mecha* woreda rural development office. For the interview, both semi-structured and structured questionnaires were used to assess the contribution of the project on the life of the farming community. Field observations such as irrigation system structures and irrigation practices and types of crops under irrigation were parts of primary data. Secondary data such as weekly, monthly and annual based achievement reports and scheme management profiles were used to enrich primary sources.

Prior to the actual survey, preliminary information based on informal discussions with community members and block controllers in the command area at the grass-root levels were gathered.

To increase data validity and reliability, six enumerators who have BA degree and are fluent in the local language (Amharic) were selected and trained on how to present the questions and then they conducted the interview under the researcher's supervision (Figure 6). Interviews were conducted by going to each kebele's village center where respondents were brought by the kebele representative and the researcher. Late afternoons and non-working days were convenient for interviewees. In addition, key informant interviews with the stakeholders were conducted by the researcher. Furthermore, informal discussions with farmers and other stakeholders were made aside to substantiate qualitative results from the questionnaire.

Figure 6: The research team (the researcher and enumerators)

Source: Own field pictures

3.6 Data Analysis and Support Software

The gathered data were coded and entered into the computer using EPI-data software. Then, the data were analyzed quantitatively with the support of qualitative analysis. Both descriptive statistics (percentages, means and standard deviation) and econometric models were employed using STATA and SPSS software. For ease of understanding, the analysis methodology is discussed in objective wise as follows.

1) ***Assess water sharing mechanisms and farmers' participation in collective irrigation management activities in the Koga irrigation development project***

This objective is intended to investigate the water sharing mechanisms that the beneficiary households used to irrigate their farm plots and assess their participation in irrigation management activities. Households were first assessed how they were selected to be beneficiaries. Then the water sharing mechanisms applied by beneficiaries were investigated. Qualitative analysis with simple descriptive statistics was used to analyze this data.

One basic phenomenon that could not be overlooked in line with water sharing practices is farmers' participation in collective irrigation management activities and the determinant factors for their participation. According to Ostrom (2010), beneficiaries' collective action bind by rules and agreed norms have a significant role in effective irrigation water management. However, the levels of participation vary across members of the group accompanied by a combination of socio-economic, institutional and resource-related factors. As a result, a respondent might be participating in one activity but not in others. In such circumstances, it is logical to consider the multidimensional nature of activities and generate a composite index that captures the greatest number of possible collective activities in which farmers are expected to involve in. Hence, following Muchara *et al.* (2014) and Manyong *et al.* (2006), PCA was used to generate a composite index of collective participation. PCA reduces the number of variables in an analysis by describing linear combinations of variables that contain most of their information (Manyong *et al.*, 2006). The variables representing collective action are not orthogonal, but PCA is used to reduce the dimensionality of variables and decompose variations in the variables into orthogonal components.

Respondents rated their participation level in a wide list of irrigation management activities. Following Muchara *et al.* (2014), a total of 8 activities were identified, which were grouped into three main themes, namely (i) labor-based participation (ii) participation in decision making and (iii) participation in regulation and control (Table 2). In addition, Muchara *et al.* (2014) have used financial-based activities, but it might not work for this case study. Because the participation level of irrigators in financial-based activities in the KIDP was equal with a fixed amount of money paid in annual base for the service. So, this variable was dropped. Participation in collective activities was ranked using a 5-point Likert scale from 0 if a farmer is not involved in a given activity, to 4 if he/she is highly involved. The rankings then used to compute the participation index (PI) using PCA for individual farmers in water-related activities.

Explicitly, the levels of participation in collective activities by farmers are assumed to have equal weights. This may be queried where smallholder farmers value the forms of contribution differently. The complexity of allocating specific values to the various forms of participation resulted in the current implicit assumption about equal weights. The PI was therefore used as a proxy to measure farmers' involvement in collective activities (Muchara *et al.*, 2014).

Table 2: Description of variables for PCA model to generate participation index

Themes of participation	**Forms of collective participation**	**Level of participation**	**Sources**
Labor-based participation	participate in canal repair and maintenance	0=not involved; 1=low involvement; 2= average; 3= high; 4= very high	(Fujiie *et al.*, 2005; Muchara *et al.*, 2014; Ostrom, 2010, 2014)
Participation in Decision making	Attending meetings		
	Contributing ideas in water related issues		
	Attending trainings		
Participation in Regulation and control	Reporting unlawful water use		
	Reporting and controlling theft of irrigation infrastructure		
	Reporting and controlling of water leakages /runoff		
	Reporting any infrastructure damages		

Once having the index, it worthy to assess why households differ in their PI. Therefore, the study has extended the idea into identifying the factors that affect farmers' participation in collective irrigation management activities. As a result, the derived PI indices from PCA for each of the sample households were used as the dependent variable in a Tobit model. We tried to fix the Seemingly Unrelated Regression model (SUR) to identify influencing factors, but we face inadequacies such as; 1) the model uses each activity separately as an outcome variable (proxy of participation) which does not adequately represent collective participation, 2) even if the model identifies the influencing factors for each variable in a dimension, one, it is not the focus of the study that it intends to identify factors for collective participation (represented by a composite PI), second, since variables in dimensions are large, it could be very complicated for interpretation in this case, 3) the model couldn't censor a PCA-generated index and does not show the intensity of farmer's participation. The use of the PCA and Tobit model, therefore, overcomes the problems. As a result, following previous studies such as Manyong *et al*. (2006) and Muchara *et al.* (2014), a censored *Tobit* regression model was employed to estimate the determinant factors influencing farmers' participation in collective irrigation water management activities (Z), i.e., user attributes, physical or resource attributes, institutional attributes and the form and level of participation (participation index). The participation index (σ) is the dependent variable. Given the right- and left-censoring at a minimum (σ min) and maximum (σ max) score, respectively, the 2-limit *Tobit* model (Maddala, 1983) cited in (Muchara *et al.* (2014)) is specified as follows:

$\sigma_i^* = \beta'(Z_i) + \varepsilon_i 1$

Where: σ_i^* is an unobservable latent response variable

Z_i is an observable vector of explanatory variables

β' is a vector of parameters to be estimated

ε_i is a vector of independently and normally distributed residuals with a common variance θ.

Then the actual model can be represented as follows:

$$\sigma_i = \sigma_{min} \; if \; \sigma_i^* \leq \sigma_{max}$$
$$= \beta'(Z_i) + \varepsilon_i \; if \; \sigma_{min} \leq \sigma_i^* \leq \sigma_{max}$$
$$= \sigma_{max} \; if \; \sigma_i^* \geq \sigma_{max} \qquad (1)$$

With this specification of participation variable parameters, the model is estimated by maximizing the following corresponding log-likelihood function (Maddala, 1986):

$$L(\beta, \theta) = \prod_{\delta i = \delta min} \Phi\left(\frac{\delta_{min} - \beta' Z_i}{\theta}\right) \prod_{\delta i = \delta i^*} \frac{1}{\theta} \varnothing \left(\frac{\delta_i - \beta' Z_i}{\theta}\right):$$

$$\times \prod_{\delta_i - \delta_{min}} \left[1 - \Phi\left(\frac{\delta_{max} - \beta' Z_i}{\theta}\right)\right]$$

Where: Φ and Ø are the standard normal density and distribution functions, respectively.

Table 3: Description of explanatory variables for Tobit model and expected signs

Explanatory variable	Description and Expected effects	
Age of household head	Continuous (in year)	-
Family size	Continuous (in number)	+
Education	Continuous (years spent in formal school)	-
Average annual income in irrigation agriculture	Continuous (in birr)	+
Average Irrigated land size per hh	Continuous (in ha)	+
Average amount farmers pay for irrigation management	Continuous (in ETB)	-
Gender of household head	Dummy (1 if HH head is male; 0 otherwise)	+
Position of farm plot from the main canal	Categorical (1 =Upper, 2 = Middle,3 = Tail-end)	±
Frequency of water-related meeting calls	Dummy (1 if it is regular; 0 less regular)	-
Satisfaction with the work of committee	Dummy (1 if HH is satisfied; 0 otherwise)	+
Perception of water sharing equality	Dummy (1 if HH perceive equal; 0 otherwise)	+
Training in irrigation water management	Dummy (1 if there is training; 0 otherwise)	+
household has been involved in water-related conflict in the past year	Dummy (1 if HH involved; 0 otherwise)	-
Perception of participatory approach of the system	Dummy (1 if HH perceived it is participatory; 0 otherwise)	+
Perceived rigidity of rule and regulations in the system	Dummy (1 if HH perceives; 0 otherwise)	-
Access to credit service	Categorical (0=no access, 1=small, 2=medium, 3=high)	+
Access to extension service	Dummy (1 if HH could access; 0 otherwise)	+
Membership of individual irrigators to a water user association	Dummy (1 if HH is a member; 0 otherwise)	+

Source: adapted from (Fujiie *et al.*, 2005; Muchara *et al.*, 2014; Ostrom, 2010, 2014) and Olson (1965)

2) Identify determinants of farmers' crop choice decision under irrigated agriculture

Following Ojo *et al.* (2013), Ayele *et al.* (2015), Greig (2009), Gecho *et al.* (2014) and Deressa *et al.* (2009), this study employed multinomial logit (MNL) model to analyze the crop choice of irrigating farmers involving multiple continuous and unordered discrete variables. Based on the specification of W. H. Greene (2003), this model is used to predict the probabilities of more than two possible discrete outcomes from a categorically distributed dependent variable, given a set of independent variables. Unordered-choice models can be motivated by a random utility model (W. H. Greene, 2003). For the i^{th} consumer faced with J choices, suppose that the utility of choice j is:

$$U_{ij=}V_{ij}^{'}\beta + \epsilon_{ij} \qquad (2)$$

Based on preliminary survey and secondary data sources, the main crops grown in the KIDP were identified and then categorized in to six groups. The categories include cereal-only, vegetable-only, cereal-vegetable, vegetable-cash crop, cereal-cash crop and cereal-vegetable-cash crop and are mutually independent alternatives. Hence, it is assumed that the owner of an irrigated field optimizes the expected gain through choosing the crop that would best benefit him for a given attributes. If a farmer has J alternatives, indexed j=1, 2 …J., the expected benefit of crop j for individual i is denoted as u_{ij}. u_{ij} can be written as a deterministic component plus a random component: V_{ij} + $\mathcal{E}_{ij}$, where V_{ij} is a function of characteristics specific to individual i and $\mathcal{E}ij$ is a random error. Further, it is assumed that V_{ij} takes the form βjXi, where β_j is a vector of parameters associated with the jth crop choice and X_i is a vector of explanatory variables. If the farmer makes choice j in particular, then it is assumed that the profit is the maximum among the J profits. Hence, the statistical model is driven by the probability that choice j is made, if and only if $Prob(u_{ij} > u_{ik})$ for all other $k\#j$.

Let Y_i be a random variable that indicates the choice made, and then the probability of individual i choosing crop j is:

$$\begin{aligned} prob(Y_i = j) &= prob(u_{ij} > u_{ik}) \\ &= prob(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik}) \\ &= prob\left(\varepsilon_{ik} - \varepsilon_{ij} < V_{ij} - V_{ik}\right) \qquad (3) \end{aligned}$$

W. H. Greene (2003) explained that the estimated equations provide a set of probabilities for the J + 1 choices for a decision maker with characteristics x_i. If $\beta_j^* = \beta_j + q$ for any vector q, then re-computing the probabilities defined below using β_j^*instead of β_j produces the identical set of probabilities because all the terms involving q drop out by which indeterminacy is removed in the model. A convenient normalization that solves the problem is $\beta_0 = 0$. This is because, the probabilities for all the choices must sum up to one, and so only J parameter vectors are needed to determine the J + 1 probabilities. Therefore, the probabilities are:

$$prob(Y_i = j/X_i) = \frac{e^{\beta_j^{'} X_i}}{1 + \sum_{j=1}^{j} e^{\beta_j^{'} X_i}} forj = 0,1, \ldots, J, \beta_0 = 0 \qquad (4)$$

Using this model, estimation was made to know how the independent variables affect the probability of choosing crop. To do so, it is useful to note that the odds ratio, P_j / P_k, does not depend on the other choices, which follows from the independence of disturbances in the original model. From a behavioral viewpoint, this fact is not very attractive. The log-likelihood can be derived by defining, for each individual, $d_{ij} = 1$ if alternative j is chosen by individual farmer i, and 0 if not, for the $J - 1$ possible outcomes. Then, for each i, one and only one of the d_{ij}'s is 1. The log-likelihood is a generalization of that for the binomial probit or logit model which is specified as:

$$InL = \sum_{i=1}^{n} \sum_{j=0}^{j} d_{ij}\, in\, prob(Y_i = j)$$

Where, InL is the log likelihood function and d choice indicator. The derivatives have characteristically simple form,

$$\frac{\partial InL}{\partial \beta_i} = \sum (d_{ij} - p_{ij})\, x_i, for\ j = 1, \ldots . J \qquad (5)$$

The coefficients in this model are difficult to interpret. It is tempting to associate β_j with the j^{th} outcome, but that would be misleading. By differentiating equation (5), the marginal effects of the characteristics on the probabilities could be found:

$$\delta_j = \frac{\partial p_j}{\partial x_i} = P_j \left[\beta_j - \sum_{k=0}^{J} P_k \beta_k\right] = P_j[\beta_j - \overline{\beta}] \qquad (6)$$

Therefore, every sub vector of β enters every marginal effect, both through the probabilities and through the weighted average that appears in δ_j. These values can be computed from the parameter estimates.

For the ease of analyses, the crop chosen on each sample irrigated site were identified as dependent variable. Some of important explanatory variables included in the model to determine the crop choice decisions are described in Table 4.

Table 4: Description of variables used in the MNL

Explanatory Variable	**Description**	**Expected sign**
Gender of household head	Dummy (1 if household head is male; 0 otherwise)	+
Age of household head	Continuous (in years)	+
Family size	Continuous (number of dependents in household)	+
Education	Continuous (years spent in formal school)	+
Farming experience	Continuous (in years)	+
Yield expectation	Dummy (1 if farmer expects high yield from a crop;0 otherwise)	-
Crop marketability	Categorical (1 if marketability is high; 2 if it is medium; 3 if it is low)	±
Crop In-home utilization	Categorical (1 if crop is highly utilized; 2 if it is medium; 3 if it is low)	±
Input costs	continuous (amount of birr spent for input/cropping season)	-
Input supply	Dummy (1 if there is supply; 0 otherwise)	+
Crop water need	Categorical (1 if crop need is highly;2 if it is medium;3 if it is low)	-
Climate change Resilient	Dummy (1 if HH perceived the grown crop is resilient; 0 otherwise)	±
Crop maturity period	Continuous (number of months spent to grow)	+
Expertise advise	Dummy (1 if HH get advice; 0 otherwise)	+
Access to market	Dummy (1 if there is market access; 0 otherwise)	+
Farm holding size	Continuous (land holding size in hectare)	+
Water supply adequacy	Categorical (1 if there is high supply; 2 if it is medium; 3 if it is low)	+

Source: adapted from (Ayele *et al.*, 2015; Ojo *et al.*, 2013; Rahman, 2008)

3) Examine the impact of irrigation on household food security

i. Measuring food security: *applying multidimensional household food security index (MFI)*

In the literature, food security has been measured through different measurements, but there is no perfect measurement that captures all its aspects (Wineman, 2014). This implies that food security has no single measure that meets the criteria valid and reliable, comparable over time and space, and captures different elements (Coates, 2009; Maxwell *et al.*, 2013). Some of the widely applied food security measurement indicators in the literature are; household dietary diversity score (Kennedy *et al.*, 2015), the coping strategies index (CSI) or its recent version of reduced coping strategies index (rCSI) (Maxwell, 1996), the household food insecurity access scale (HFIAS) (Headey & Ecker, 2012) and global food security index (GFSI) (EIU, 2013). However, according to Maxwell *et al.* (2013), these and other food security measures cannot capture multiple dimensions of food insecurity inherent in the definition. Therefore, relying on one measurement is followed by the risk of serious misclassifications. Given the multidimensional nature of food security, practitioners and policymakers have long recognized the need for a variety of means of measurement (Kennedy *et al.*, 2015). As a result, few scholars such as Demeke *et al.* (2011) and Wineman (2016) have tried to combine food security indicators into a single composite index. Later, methodologically different from others, Maxwell *et al.* (2013) have developed a recent multidimensional household food security index (MFI) to capture many dimensions of food security. It is theoretically and empirically well-done indicator. It has been developed from seven common food security indicators through a comparative empirical analysis. They are coping strategies index (CSI), reduced coping strategies index (rCSI), household food insecurity and access scale (HFIAS), the household hunger scale (HHS), food consumption score (FCS), household dietary diversity scale (HDDS), and a self-assessed measure of food security (SAFS).

According to Maxwell *et al.* (2013), the advantages of MFI over the other stand-alone measures are threefold. First, it is data-rich and capturing multiple dimensions of food security. Second, the range of sensitivity to food insecurity is wider that is it senses both milder food insecurity manifestations and severe conditions. Third, by taking an algorithmic approach, it avoids the pitfalls of arbitrary quantitative food security cut-offs along a raw score.

Therefore, this illustrative composite index is applied in this research to capture the prevalence and severity of food insecurity through addressing the following questions: is there food (in) security difference among irrigation and non-irrigation user households? What is the nature of the food insecurity problem in the study area? And through what avenues does irrigation affect food security?

Construction of dimensions, variables and household categories

Following Maxwell *et al*. (2013), households were divided into categories of "food secure," "mildly food insecure," "moderately food insecure," and "severely food insecure". Except for SAFS, each question has an answer from a similar set of four responses which are often, sometimes, rarely, and never, with the exact meaning of these responses varying by the context of the question. The response for SAFS is corresponding to severely food insecure (4 or worst), moderately food insecure (3), mildly food insecure (2), and food secure (1). Though a choice of cut-offs for these categories is ultimately subjective, a gold standard of an algorithmic approach was the food security definition; individuals would experience food insecurity if they experienced any one of the manifestations described in the definition, at any time.

In this study, households were classified under "severely food insecure category" when the response to any of the first six questions is worst or second-worst (from NOEAT to SENDEAT) and any worst response to any of the next seven questions (from PULSE to NOTWNT). In the other edge, households under "food secure" can only be classified if they give the optimal response for questions 1–13, at least the optimal or second-best response for questions 14–19, and anything but the worst response for questions 20–24 (Table 5 and Annex 3 and Annex 4).

Table 5:The cut-offs of multidimensional household food security categories

Responses	**MFI Categories**	**% of hhs in MFI categories**
If Any of NOTEAT-SENDEAT=never, and PULSE & GRAIN=often, and EATSEED-NOTWNT=never, and LIMVAR- WORRY=never or rarely, and SAFS= food secure or mildly food secure, and DAIRY-VEGET= rarely or sometimes or often	Food secure	$\frac{n=1}{N}$x100
If PULSE or GRAIN= sometimes, or any of EATSEED-NOTWNT=rarely, or any LIMVAR-WORRY =sometimes, or SAFS=moderately food insecure, or any of DAIRY-VEGET= never	Mildly food insecure	$\frac{n=2}{N}$x100
If any of NOTEAT-SENDEAT=rarely, or PULSE or GRAIN=rarely, or any of EATSEED-NOTWNT=sometimes, or any of LIMVAR-WORRY=often, or SAFS=food insecure	Moderately food insecure	$\frac{n=3}{N}$x100
If any of NOTEAT-SENDEAT= sometimes or often, or any of PULSE or GRAIN=never, or any of EATSEED-WORRY=often, or SAFS=food insecure	Severely food insecure	$\frac{n=4}{N}$x100

Note: $\boldsymbol{n}$ is the number of households with MFI category 1,2,3 &4 that is food secure, mildly food insecure, moderately food insecure & severely food insecure, respectively

$\boldsymbol{N}$ is total number of households in the MFI category

Source: adapted from Maxwell *et al.* (2013).

ii. Measuring the impact of irrigation on food security: Propensity score matching (PSM)model specification

Controlling sample selection biases is appeared to be one of the most difficult issues in most impact assessment studies. This problem occurs when the researchers want to know the effect of a treatment on the treated outcome but cannot observe the outcomes with and without treatment on the same individual at the same time (Friedlander and Robins, 1995) cited by Kuwornu &Owusu (2012). Thus, by directly comparing mean outcomes between the two treatment groups an unbiased estimate of the average treatment effect cannot be obtained (Austin, 2011). Because the treated group might be systematically different from the non-treated group in their characteristics rather than the impacts of the treatment.

Therefore, this study uses propensity score matching (PSM) framework to estimate the impact of irrigation on household's food security to controlling the selection bias. Impact through this outcome variable was obtained by matching an ideal comparative group (non-irrigation users) to the treatment group (irrigating farmers) on the basis of propensity scores (P-scores) of X. Both treated and control sample households were taken from the similar agro-ecological environment.

To develop the PSM framework, let Y_i be the outcome variable of household i, such that Y_{1i} and Y_{0i} denote household food security with and without access to irrigation, respectively. A dummy variable h_i denotes irrigation access by household i, where $h_i = 1$ if the household has access to irrigation and, $h_i = 0$ otherwise.

The outcome observed for household i, is defined as:

$$Y_i = h_i Y_{1i} + (1 - h_i) Y_{0i} \qquad (7)$$

The impact of irrigation on household i's food security is given by;

$$\Delta_i Y_i = Y_{1i}(treated\ outcome) - Y_{0i}(counter\ factual\ outcome) \qquad (8)$$

Where Δ_i denotes the change in the outcome variable of household i, resulting from access to irrigation.

The framework assumes as there will be heterogeneity in impacts of outcome because all households with access to irrigation cannot be benefited equally with different characteristics. As a result, the average treatment effect on the treated (ATT)[4] is used to estimate irrigation effects conditional on access to irrigation.

It is represented as;

$$ATT = [E(\Delta_i | \mathrm{h_i} = 1)\ ] = \mathrm{E}[\mathrm{Y_{1i}} - \mathrm{Y_{0i}} | \mathrm{h_i} = 1] = \mathrm{E}[\mathrm{Y_{1i}} | \mathrm{h_i} = 1] - \mathrm{E}[\mathrm{Y_{0i}} | \mathrm{h_i} = 1] \qquad (9)$$

[4] There are two common evaluation parameters in impact analysis frameworks. They are the average treatment effect (ATE), the effect of treatment on the outcomes of the whole population without regards to the treatment and the average treatment effect on the treated (ATT) the effect of a treatment on the treated conditional on access to treatment (Kuwornu and Owusu, 2011).

From (9), $\mathrm{E}[\mathrm{Y}_{0i}|\mathrm{h}_i = 1$ is the missing data that represent the outcomes of irrigation participants in the absence of irrigation. However, this missing data was estimated by using the outcomes of a counterfactual group (non-irrigating), can be rewritten as:

$$[E(\Delta_i|\mathrm{h}_i = 1)] = \mathrm{E}[\mathrm{Y}_{1i} - \mathrm{Y}_{0i}|\mathrm{h}_i = 0] \quad (10)$$

Without controlling for the unobservable heterogeneity, (10) can be shown to consist of a bias in addition to the impact estimate. Subtracting and adding $\mathrm{E}[\mathrm{Y}_{0i}|\mathrm{h}_i = 1$ to the right-hand side of (10) gives

$$E[Y_{1i}\,|\mathrm{h}_i = 1] - E[\mathrm{Y}_{0i}|\mathrm{h}_i = 0] - \mathrm{E}[\mathrm{Y}_{0i}|\mathrm{h}_i = 1] + \mathrm{E}[\mathrm{Y}_{0i}|\mathrm{h}_i = 1] \quad (11)$$

This implies that if non-irrigating farmers are selected for comparison with irrigating farmers without controlling for the non-random irrigation assignment, + or – missing data (i.e.,$\mathrm{E}[\mathrm{Y}_{0i}|\mathrm{h}_i = 1$) amount will be added to the estimates of irrigation impact on household outcomes which, in turn, will under or overestimate the result.

It is expressed as

$$[\mathrm{Y}_{0i}|\mathrm{h}_i = 0] = E[\Delta_i|\mathrm{h}_i = 1] + \overset{Bias}{\{E[Y_{0i}|\mathrm{h}_i = 1] - E[Y_{0i}|\mathrm{h}_i = 0]\}} \quad (12)$$

To eradicate the bias, the method has identified and match irrigator households within the non-irrigators that are similar in observable characteristics (x).

This was done by estimating propensity scores (P-scores)[5] of x in which x is the set of basic characteristics that determine irrigation participation. The propensity score of each farmer measures the tendency to join the irrigation. The larger the score, the more likely the farmer is to join the irrigation. The propensity score was estimated using a probit regression model, in which treatment status was regressed on observed baseline characteristics.

Specifically, the propensity score was estimated based on covariates x.

$$\hat{e}(x) = p(I = 1|x) \quad (13)$$

Which states that those in $h_i = 1$ and $h_i = 0$ with the same $\hat{e}(x)$ will have the same distribution on the covariates x.

[5] Propensity score is a balancing score that estimated based on relevant observed covariates (characteristics that are not affected by the choice of irrigation) in which the distribution of x given the balancing score is the same between the treated and untreated subjects.

The second step was matching farmers into groups of similar propensity scores. Since exact matching is rarely possible (Setboonsarng *et al.*, 2008), different matching methods were used to select the "best" non-irrigating group for the irrigating group (common support assumption).

$$\{E[Y_{0i}], h_i = 1, X_i = x\} = \{E[Y_{0i}], h_i = 0, X_i \approx x\} \quad (14)$$

Once a matched sample has been formed, the heterogeneous impact (ATT) of irrigation on household food security can then be estimated using Equation (15).

$$ATT = [E(\Delta_i | \mathrm{h_i} = 1)] = \frac{1}{\mathrm{h_i}} \sum (\mathrm{Y_{1i}} - \mathrm{E[Y_{0i}]})\mathrm{h_i} = \frac{1}{\mathrm{h_i}} \sum \Delta_i \mathrm{h_i} \quad (15)$$

Finally, to see the impact of irrigation on food security, MFI was used as an outcome variable. Even though there is no consensus on what type of independent variables should be included when estimating propensity scores (Austin, 2011), for this study, household head's gender, family size, private landholding size, education level, a dummy of access to extension services, age, and farming experience were selected after robustness checks.

Table 6: Description of explanatory variables for Probit model to calculate propensity score

Explanatory variable	**Description**	**Expected effects**	**Sources**
Age of household head	Continuous (in year)	+	(Austin, 2011; Kuwornu & Owusu, 2012; Setboonsarng *et al.*, 2008)
Family size	Continuous (in number)	+	
Education	Continuous (in years school)	+	
Average private land size	Continuous (in ha)	+	
Gender of household head	Dummy (1 if male; 0 otherwise)	-	
Farming experience	Continuous (in year)	-	
Access to extension service	Dummy (1 if access; 0 otherwise)	+	

4) Examine the impact of irrigation on household on poverty reduction

i. Poverty analysis: application of multidimensional poverty index (MPI)

The measurements that have been applied to measure poverty in the literature were mainly focused on income/consumption expenditure indicators. However, this mono-dimensional poverty measurement does not consider the multidimensional nature of poverty and hence it failed to address the structures of poverty reduction. As a result, this research employed the multidimensional poverty index (MPI) developed by OPHI and UNDP in 2010. The Alkire_Foster (2015) methodological approach (AF methodology hereafter) is the main methodology.

The main purpose of applying MPI based on the AF methodology was to measure acute poverty in which the proportion of households who experienced multiple deprivations and the intensity of such deprivations are identified. By taking the joint distribution of deprivations into account, it tracks the same household across multiple dimensions and counts the number of deprivations simultaneously experienced by the household. In this case, household members' combined achievements were used as a unit of identification for a population-wide measure, and all household members received the same deprivation score.

With the AF method, many key decisions are left to the researcher (Alkire & Foster, 2011). As shown in the subsequent section, this study, therefore, followed normative judgments to select the measure's purpose, unit of analysis, dimensions, deprivation cut-off, weights or values, and poverty cut-off.

Dimensions, Indicators, Weight and Thresholds

Dimensions are conceptual categories into which indicators are arranged (possibly weighted) for intuition and ease of communication (Alkire *et al.*, 2015). The deprivation dimensions and thresholds considered here were chosen with reference to the standard of living and public consensus about people's values in Ethiopia. Accordingly, by following Neubourg *et al.* (2010) four deprivation dimensions (education, health, living standards and productive assets) with ten indicators were selected (Table 7). The first three are internationally acknowledged dimensions, but are modified into the local context. The fourth dimension was selected by assuming that it is contextual to the study area and relevant to the country's policies. All the indicators were defined at the household level, which is the unit of analysis.

Within this approach, indicators were first assigned for the household poverty line and then they were aggregated into predefined dimensions of poverty, which are in turn combined into an overall poverty index. Even though there is no a priori reason to assume that the indicators used are all equally relevant across the sample population (Neubourg *et al.*, 2010), for the ease of interpretation, this study follows equal weighting strategy among dimensions and indicators.

Following (Alkire & Foster, 2009), the study used a dual cut-off approach to identify multidimensional poor households. The first cut-off is used to determine whether a household is deprived in a particular indicator. Determinations of threshold given for each indicator were decided on the glance of theoretical assumptions, practicalities and policy relevancies. The second cut-off is the weighted sum of indicators which are counted towards identifying the multidimensional poor. This cutoff will show what combined share of weighted deprivations is sufficient to identify a household as poor. Following Alkire *et al.* (2015), households were defined as MPI poor if they are deprived in at least a third of the weighted indicators ($k \geq 33$) set out in the table below.

Table 7:The dimensions, indicators, deprivation thresholds and weights of the MPI

Dimension	Indicator	Deprived if…….	Weight
Education	Years of Schooling	No household member has completed eight years of Schooling	1/8
	Child school attendance	Any school-age child in years up to 7 is not attending school.	1/8
Health	Child Mortality	Any child has died in the household in the year under study.	1/8
	Access of health center/facility	The household has no access to health facility or access more than an hour trip	1/8
Living Standards	Electricity	The household has no electricity, generator or solar.	1/16
	Improved Sanitation	The household has no Improved sanitation	1/16
	Safe Drinking Water	The household does not have access to safe drinking water (according to MDG guidelines) or safe drinking water is more than a 30minutes walk from home, round trip.	1/16
	Roofing	The household has lived in a house thatched by grass.	1/16
Productive assets	Livestock index	The household does not own more than one group or two numbers in one group of beef cattle, milk cow, breeding bull, farm ox, goat and/or sheep and equine (donkey/horse/mule)	1/8
	Durable asset	The household own none of the following: Car, Bajaj, motorbike, bicycle, cassette player, radio, mobile, hand insecticide pump and water pump	1/8

Source: adapted from Neubourg *et al.* (2010) and Alkire *et al.* (2015)

The thresholds selected for the two education indicators are based on the Ethiopian education policy that describes children of 7 years should be enrolled in school and everyone within a country should at least complete primary school.

There are two health dimension indicators. The first indicator which lies on Ethiopian health policy is access to the health center. The household is considered as deprived when it has no access to the health center or accessed after more than an hour trip; assume that the availability of health stations prevents child death through counseling mothers about nutrition and hygiene. The second indicator in health dimension is child mortality. Since most child deaths caused by infectious disease are preventable (Alkire & Foster, 2011), a household is considered to be deprived if there has been at least one observed child death in the household under the year of study. Within the living standard dimension, access to electricity/ type of lighting source is a frequently used indicator on various welfare questionnaires. For example, Alkire *et al.* (2015) and Neubourg *et al.* (2010) use electricity, generators/solar power as indicators to estimate the quality of life in Ethiopia and Senegal, respectively. Analogously, a household is considered as deprived if it does not own either of the listed lighting sources. For improved sanitation threshold, a household is assumed to be non-deprived, if it is provided with sanitation facilities such as sewers or septic tanks, poor-flush latrines and simple pit or ventilated improved pit latrines, but when they are not publicly shared (Alkire *et al.*, 2015). According to the MDG guideline and Ethiopian government, a household has access of safe drinking water when the water source is either of the following types: piped water, public tap, borehole or pump or developed spring and when it is within a distance of 30 minutes' round trip. Roofing is another non-MDG indicator of the quality of house for households. Scholars such as Alkire *et al.* (2015) have use flooring categories (dirt, sand or dung floor) to assess the quality of housing in Ethiopia. However, in this case, roofing will be used in place of flooring because house floor is commonly similar in the studied society but their house quality varies in their roofing material such as grass and steel sheet. A house thatched with grass is, therefore, considered as an inferior house type in this study.

The final dimension covers the ownership of productive assets. Since the research setting is a rural area, both livestock and durable asset indicators will provide rudimentary information about the farmer's farming equipment assets and functions as an income proxy. As per the context of the study area, a household is considered as deprived if it does not own more than one group or two numbers in one group of livestock assets such as beef cattle, milk cow, breeding bull, farm ox, goat and/or sheep and equine (donkey/horse/mule). By considering the current farmers' ability to afford an asset in the study area, a threshold for durable asset was set in a way that a household is considered as non-deprived if it owns any of the following: car, Bajaj, motorbike, bicycle, cassette player/radio, mobile or hand insecticide pump.

In summary, the analysis of poverty follows three steps. First, the proportion of households under multiple deprivations was identified. Second, multidimensional poor households were identified when they are deprived in $\frac{1}{3}$ of dimensions. Third, poverty profile was constructed for irrigators and non-irrigators.

Mathematical expression

Once the indicators and their corresponding cut-offs have been selected, the next step is defining the weights for each dimension and indicator. In the MPI methodology, the dimensions are equally weighted so that each of them receives a ¼ weight. The indicators in each dimension are also equally weighted. Thus, each indicator within the health, education and productive asset receives a $1/8$ weight and each indicator in the living standard dimension receives a 1/16 weight.

It is defined as the indicator i weight as wi, with $\sum_{i=1}^{4} wi = 1$

Next, each person is assigned a deprivation score according to his or her deprivations in the component indicators. The deprivation score of each person lies between 0 and 1. The score increases as the number of deprivations of the person increases and reaches its maximum of 1 when the person is deprived in all component indicators. A person who is not deprived in any indicator receives a score equal to 0.

That is: $ci = \frac{w1}{1} + \frac{w2}{2} + \cdots \frac{wd}{d}$

Where ci is the composite deprivation score ranging 0 to 1, $i = 1$ if the person is deprived in indicator i and $i = 0$ otherwise, and wi is the weighted attached to indicator i with $\sum_{i=1}^{d} wi = 1$.

Finally, poverty is analyzed by emphasizing on multidimensional headcount, the adjusted headcount, the mean number of deprivations, the poor and the non-poor, as well as the decomposed contributions of the single dimensions towards the overall headcount.

The adjusted headcount ratio, ($Mo(X; z)$), can be written as the product of two partial indices. The first partial index is the headcount ratio or poverty incidence $H = H(X; z)$ which is the proportion of the population that is poor. It is defined as $H = q/n$, where q is number of HHs identified as poor among total population $\boldsymbol{n}$ using the dual-cutoff approach.

The second index (A) is poverty intensity that is the average deprivation score across the poor. Notice that the censored deprivation score $c_i(k)$represents the share of possible deprivations experienced by a poor person $\boldsymbol{i}$. So, the average deprivation score across the poor is given by $A =$

$\sum_i^n = 1\ c_i(k)/q$. This partial index conveys households who experience simultaneous deprivations in a higher fraction of dimensions have a higher intensity of poverty and are poorer than others having a lower intensity (Alkire *et al.*, 2015).

Thus, Mo is given by

$$Mo = H \times A \tag{16}$$

Or

$$Mo(X;z) = \mu\big(c(k)\big) = H \times A = \frac{q}{n} \times \frac{1}{q}\sum_{i=1}^{q} c_i(k) = \frac{1}{n}\sum_{i=1}^{n} c_i(k) = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{d} w_j g_{ij}^0 \tag{17}$$

ii. Estimating irrigation impact of poverty reduction: the switching regression model

The evaluation of the impact of technology adoption on the household outcome is hampered by the fact that the "before" and "after" activities of a household are rarely observed. Instead, researchers are usually left to compare adopters with non-adopters (Fuglie and Bosch, 1995). But, due to the possible systematic differences in mode of access and participation in a project, sample selection bias may result. In this study, irrigation participation becomes the selection criterion governing observation of household poverty. Depending on the assumption regarding the relationship between the residuals of the selection regime and the outcome equations, both exogenous and endogenous switching regressions can be developed (Kuwornu & Owusu, 2012). Let I_i represents an irrigation participation dummy where $i \in [0,1]$, an irrigation selection criterion function can be expressed as

$$I_i = y'Z_i + u_i \tag{18}$$

Where, Z_i is a vector of household characteristics as well as instruments deemed to influence irrigation participation or adoption decision of household i, y is the vector of parameters to be estimated, and u_i is the error term.

Based on equation (18), let Y_i represent the level of household multidimensional poverty which will be observed for two different regimes (1) irrigator (2) non-irrigator (Fuglie & Bosch, 1995; Kuwornu & Owusu, 2012).

$$Regme1: Y_{1i} = \beta_1' X_{1i} + v_{1i}, \quad if\ and\ only\ if\ y'Z_i + u_i > 0: irrigators\ (I_i = 1) \tag{19}$$

$$Regme2: Y_{2i} = \beta_2' X_{2i} + v_{2i}, \quad if\ and\ only\ if\ y'Z_i + u_i \leq 0: non-irrigators\ (I_i = 0) \tag{20}$$

Where, X_i is a vector of exogenously determined variables of household i included in Z, β is the coefficient vector and v_i, the residuals.

Following Kuan (2002) and Kuwornu &Owusu (2012), this research first assume that the unobserved residual effects on poverty between irrigators and non-irrigators are independent of the unobserved effects on irrigation participation condition.

$$E[v_{1i}|I_i = 1] = E[v_{2i}|I_i = 0] = 0, and\ cov\ (u_i v_i) = 0$$

This implies that sample partitioning between irrigators and non-irrigators is entirely exogenous to their behavior so that an exogenous switching structure results, as in equations (19) and (20).

The unconditional expectation of these models can be expressed as applying least squares to equations (21) and (22) gives consistent estimate of the β.

$$\mathrm{E}[Y_{1i}|x_{1i}] = \beta_1' X_{1i} \quad (21)$$

$$\mathrm{E}[Y_{2i}|x_{2i}] = \beta_2' X_{2i} \quad (22)$$

However, there is a high likelihood that uncontrolled factors (e.g. farmer's inherent managerial ability) in the disturbance term,u_i, influencing participation in irrigation also simultaneously will influence the level of outcomes (Kuwornu & Owusu, 2012) so that $cov(u_i v_i) \neq 0$. Under this situation sample separation between irrigators and non-irrigators become endogenous to their behavior, and governed by an irrigation participation regime. In order to obtain consistent standard errors, the full information maximum likelihood (FIML) method was employed to simultaneously fit the binary and continuous parts of the model. Here, the error terms v_{1i}, v_{2i} and u_i are assumed to follow a trivariate normal distribution with mean vector zero and covariance matrix $\sum$, i.e., $(u, v_{1,} v_2)' \sim N\ (0, \sum)$(Di Falco *et al.*, 2011; Kuwornu & Owusu, 2012).

$$\sum = \begin{bmatrix} \sigma_u^2 & \sigma_{1u} & \sigma_{2u} \\ \sigma_{1u} & \sigma_1^2 & . \\ \sigma_{2u} & . & \sigma_2^2 \end{bmatrix}$$

Where, σ_u^2 is the variance of the error term in the selection, σ_1^2 and σ_2^2 are the variances of the error terms in the continuous equations; σ_{1u} is the covariance of u_i and v_{1i}; and σ_{2u} is the covariance of $u_i$and v_{2i} . Note that, the covariance between v_{1i} and v_{2i} is not defined since Y_{1i} and Y_{2i} are never observed simultaneously (reported as dots in the covariance matrix). It is assumed that $\sigma_u^2 = 1$, since y is estimable only up to a scalar factor (Maddala, 1986).

The expected (conditional) outcomes of a household for the two regimes are expressed as

$$E(Y_{1i}|\text{I} = 1) = \beta'_1 X_{1i} + \sigma_1\rho_1 W_{1i} \quad (23)$$

$$E(Y_{2i}|\text{I} = 0) = \beta'_2 X_{2i} + \sigma_2\rho_2 W_{2i} \quad (24)$$

Where σ_1 and σ_2 are the standard deviations of the two outcome equations, respectively; ρ_1 is the correlation coefficient between v_{1i} and u_i; ρ_2 is the correlation coefficient between v_{2i} and u_i. W_{1i} and W_{2i} are the non-selection hazard terms for the respective regimes.

Following (Asfaw *et al.*, 2012; Di Falco *et al.*, 2011; Nonvide, 2018), the study compared the expected household MPI of the irrigators with respect to the non-irrigating farmers, and investigate the expected MPI in the counterfactual cases that the irrigators did not adopt irrigation, and that the non-irrigators did adopt. As shown in Table below, cases (a) and (b) indicates the actual expectations and the counterfactual expected outcomes are shown in cases (c) and (d).

Table 8:Conditional expectations, treatment and heterogeneity effects

Sample groups	**Decision stage**		**Treatment effects**
	Irrigate	Not irrigate	
Irrigators	(a) $E(y_{1i}/D_i = 1)$	(c) $E(y_{2i}/D_i = 1)$	TT
Non-irrigators	(d) $E(y_{1i}/D_i = 0)$	(b) $E(y_{2i}/D_i = 0)$	TU
Heterogeneity effects	BH_1	BH_2	TH

Note: (a) and (b) are the observed expected MPI; (c) and (d) are the counterfactual expected MPI

$\boldsymbol{D_i = 1}$ if farmers adopted irrigation; $\boldsymbol{D_i = 0}$ if farmers did not adopt

$\boldsymbol{y_{1i}}$**:** MPI of farmers adopted; $\boldsymbol{y_{2i}}$: MPI of farmers did not adopt

$\boldsymbol{TT}$**:** Effect of the treatment on the treated; $\boldsymbol{TU}$**:** Effect of the treatment on the untreated

$\boldsymbol{BHi}$**:** Base heterogeneity effect for farmers that adopted (i = 1), and did not adopted (i =0)

$\boldsymbol{TH = (TT - TH)}$**:** Transitional heterogeneity

Source: Adapted from (Asfaw *et al.*, 2012; Di Falco *et al.*, 2011; Nonvide, 2018)

The effect of irrigation adoption on irrigators is expressed by equation (25). It is the "treatment effect on the treated" (TT) which is the difference between cases (a) and (c) (Asfaw *et al.*, 2012; Nonvide, 2018).

$$TT = (E(y_{1i}/D_i = 1 - E(E\left(\frac{y_{2i}}{D_i} = 1\right) \quad (25)$$

Similarly, the difference between cases (d) and (b) is the treatment effect on the untreated (TU) for the non-irrigators, expressed by Equation (26).

$$\boldsymbol{TU} = E\left(\frac{y_{1i}}{D_i} = 0\right) - E\left(\frac{y_{2i}}{D_i} = 0\right) \quad (26)$$

The study differentiates the treatments effects from the heterogeneity effects. For instance, the irrigators may have more or less MPI than the non-irrigators regardless of the fact they adopted irrigation but rather because of unobservable factors that affect the MPI. This “base heterogeneity effect” is expressed in Equation (27) as the difference between cases (a) and (d) for the group of irrigators (Asfaw *et al.*, 2012; Nonvide, 2018):

$$BH1 = E(y_{1i}/D_i = 1) - E\left(\frac{y_{1i}}{D_i} = 0\right) \quad (27)$$

Similarly, for the group of non-irrigating farmers, the “base heterogeneity effect” is given by equation (28) as the difference between cases (c) and (b):

$$BH2 = E(y_{2i}/D_i = 1) - E\left(\frac{y_{2i}}{D_i} = 0\right) \quad (28)$$

Lastly, the study investigated whether the effect of adoption of irrigation is greater or smaller for irrigators or for rain-fed farmers if they did adopt. That is the “transitional heterogeneity effect” calculated as:

$$TH = TT - TU \quad (29)$$

Table 9: Description of explanatory variables which affects irrigation adoption and poverty

Description of Variables	Effect on irrigation	Effect on poverty
Age of household head (continuous)	+	+
Marital status of household head (categorical)	-	-
Length of residence (continuous)	-	-
Education level of (continuous)	+	-
Membership of Edir[6] (dummy)	-	-
Farming experience (continuous)	-	-
Household farm income (continuous)	+	+
Total land size(continuous)	+	-
Land covered by crop(continuous)	-	-
Own farm ox(continuous)	+	-
Crop marketability(dummy)	-	-
Expecting high yield(dummy)	+	+
Crop resistance of climate change(dummy)	-	-
Input supply(dummy)	+	-
Access to media (dummy)	+	

Source: adapted from (Asfaw *et al.*, 2012; Di Falco *et al.*, 2011; Nonvide, 2018)

[6] *Edir* is a traditional social/mutual aid association practiced in Ethiopia.

CHAPTER FOUR

DESCRIPTIVE RESULTS AND DISCUSSIONS

4.1 Introduction

The fourth chapter discusses the descriptive summary on the basic characteristics of the grand sample population. First, the descriptive results of basic demographic characteristics of respondents are presented. The second section deals with the findings of the socio-economic characteristics of the sample households. Under this part, the households access to some institutional services, land holding size, livestock tending capacity and rural livelihood diversification strategies are discussed.

4.2 Demographic Characteristics of Respondent Households

Basically, the descriptive summaries are specifically presented in each objective in the next subsequent chapters because the nature of the sample population varies for each objective. Here, we present the gross summary of the entire sample population to overview the basic characteristics as follows.

Table 10 shows the average age, family size and the length of residence of all sample households. The average age of respondents was 41.7 with a minimum of 18 and a maximum of 79 years. This indicates the sample population was averaged young. It is a fact that the more the population is young, the more the working labor is and the more the pressure is on the natural resources such as water and land. The average family size for the overall sample households was 5.6, with a small variation between the sample *kebeles*. This result indicates that the mean family size of the study area was larger than the mean family size of Ethiopia (4.7 persons) (CSA, 2007). The descriptive result also revealed that the sample households have been lived on average for about 37 years in their current residential *kebele*. This implies they are more familiar and adaptive to the agro-ecology and livelihood strategies in the area.

Table 10: Demographic composition of sample households by family size, age and length of residence

Variable	Mean	Std. Dev.	Min	Max
Age(years)	41.71392	12.40708	18	79
Family size (in No)	5.63038	2.017711	1	9
Length of residence(years)	37.30127	14.10198	1	79

Source: own survey data calculation

Table 11 below presents the respondents marital status, religion and gender composition. The gender composition of the sample indicated that about 32.4% were female and the remaining 67.6% were male respondents. But the figures do not reveal a household's head rather it indicates the sex of a person who has been interviewed. All of the respondents were found to be Ethiopian Orthodox Tewahido church followers. This also indicates that there is no noticed religious statistical difference between irrigators and non-irrigators. From all respondents, 88% were married and 5.3% have never been married. Divorced and widowed households were 3.5% and 2.5%, respectively.

Table 11:Marital status, religion and gender- frequency and % of respondents

Gender		Marital status				Religion	Total
Male	Female	Single	Married	Divorced	Widowed	Orthodox	
267(67.59)	128(32.41)	23(5.82)	348(88.1)	14(3.54)	10(2.53)	395(100)	395(100)

Source: own calculation; Note that numbers in parenthesis are percentages

Education status of respondents

Education has a profound effect on any economic activity. However, according to CSA and WB (2013), for the majority of the households in Ethiopia, both biological parents either do not have any education or have only some primary level education. Consistently, the average educational level of the surveyed households was found low which is 1.6 years (Table 12). The category of education level shown in the table was made after the data has been gathered. The data show that there was no respondent who has attended school after grade Ten and hence a category above grade Ten was exempted.

Table 12: Educational level of respondents-frequency and %:

Education level	Freq.	Percentage	Total Mean
Illiterate	215	54.43	
Read write	81	20.5	
1_5	59	14.9	**1.62**
6_8	22	5.5	
9_10	18	4.5	
Total	395	100	

Source: own survey data.

The descriptive statistics indicate that about 296 (%74.9) of the respondents were not attended formal education. Of them, only 81 (20.5%) have some traditional/religious school so that they can read and write while 215 (54.4%) respondents were illiterate. About 14.9% and 5.5% of respondents have attended formal education from 1-5 and 6-8 grades, respectively. The remaining 4.5% of surveyed households have completed either grade 9 or 10. The result implies that even though education is vital for the cultivation of citizens to be capable of playing the conscious and active role in the economic, social, and political life, the educational level of the surveyed households was low.

4.3 Socio-Economic Characteristics of Respondent Households

4.3.1 Access to institutional services: credit and extension services

Credit and extension service are vital for farmers which capable them to use modern technologies and cop-up seasonal problems such as food shortage. According to Awulachew *et al.* (2008), particularly, the irrigation agriculture creates demand for credit and extension services and hence irrigators have better access to extension and credit services. However, the descriptive results in Table 13 show that the majority (66.6%) of sample households had no access to credit service. The remaining 33.4 respondents had accessed a credit service ranging from small up to high amount. On the other hand, about 75% of respondents had access to extension service whereas 25% could not get the service. By extension service, it was to refer to services gained from health and agriculture experts. In general, credit service was scarcely available in the study area than the extension service.

Table 13: Access of credit and extension service-% of respondents

Variable	Freq.	Percent
Access to Credit service		
no credit	263	66.58
small credit	47	11.90
medium credit	34	8.61
high credit	51	12.91
Access to Extension service		
No	100	25.32
Yes	295	74.68
Obs.	395	100

Source: own survey

4.3.2 Land holdings

Land is one of the basic natural resources of livelihood. However, its availability to meet national and global demands for food and agriculture production have been put into sharp relief following the recent rise in commodity price levels and increased large-scale land acquisition (Dubois, 2011). In Ethiopia, the land is under state ownership since 1975 national land reform, and there have been many redistributions and adjustments since then(Woldeamlak, 2003). The frequent redistribution to accommodate newly forming households has led to the subdivision of farmlands into smaller plots. In the surveyed kebeles, the average landholding was 1.16 ha (Table 14) with a slight variation between them. This indicates the average land holding of the study population is smaller than the average household landholding size of Ethiopia (1.37 ha) (CSA & WB, 2013).

The statistics show that on average the surveyed households held 0.9 ha of land privately and 0.2 ha by rent from others. A household had covered an average of 0.89 ha by crop in the 2016/17 production year. The variation in the size of landholdings among households was significant which ranges from zero to four ha. About 38.73% (majority) of respondent households' landholdings range from 0.6-1.0 ha and only 2.53% of surveyed households had landholdings greater than 2.6 ha.

Table 14: Land holding size of sample households

Land holding	Mean	Std. Dev.	Min	Max
Total land size(ha)	1.161165	.6274755	0	4
Private land size(ha)	.9487595	.5932798	0	3.75
Rent land size(ha)	.2301899	.3899942	0	2.5
Cropped land size(ha)	.8873418	.4587501	0	3

Landholding category	**Freq.**	**Percent**
<=0.5	65	16.46
0.6-1.0	153	38.73
1.1-1.5	100	25.32
1.6-2.0	55	13.92
2.1-2.5	12	3.04
>2.6	10	2.53
Total	395	100.00

Source: own survey data

4.3.3 Livestock tending

Like all other parts of Ethiopia, livestock is an integral part of life in the study area. People in the area use animals for farming, cash source, food, the source of fertilizer/domestic fuel (i.e. dung) and transportation. Most importantly, livestock ownership was regarded as a measure of wealth in the study community. Rich and poor households were therefore differentiated by counting the number of animals that the households own. However, these days, farmers are focusing on quality of livestock than quantity and thus the sense of large number ownership is declining. Eriksson (2012) has explained that with the introduction of the *Koga* project less land has been left for grazing so that it might force households to reduce their livestock. Awulachew *et al.* (2008) have also elaborated that livestock holdings in irrigator households is lower than non-irrigators since their grazing land is changed into irrigated land.

The results in Table 15 show that beef cattle, cow, breeding bull, farm oxen, sheep and/got, bees and equine are some of the main types of livestock raising by households in the study area. Majority of the sample households did not own beef cattle (69.9%), breeding bull (88.4%), sheep and/got (56%), bees (83%) and equine (60.5%). One interesting observation was possession of farm oxen. Oxen are the engines of crop production in the study area. About 68 surveyed households had no ox. This means 17.2% of surveyed households were in a serious constraint to farm. Lack of this main resource determines the vulnerability status of a household to food insecurity and seasonal food shortage (Woldeamlak, 2003).

Table 15: Livestock farming in the study area

Livestock	Households' ownership		Total number of livestock owned by households
	Freq.	Percent	
Beef cattle	276(119)	69.9(29.1)	180
Cow	97(298)	24.6(75.4)	467
Breeding bull	349(46)	88.4(11.6)	63
Farm oxen	68(327)	17.2(82.8)	622
Sheep and/got	221(174)	56(44)	410
Bees	328(27)	83(17)	175
Equine (donkey, mule, horse)	297(98)	60.5(29.5)	180

Note: the values in parenthesis are households with ownership

Source: own survey data

4.3.4 Livelihood strategies of households in the study area

Due to land scarcity and high population pressure, farm households are widely engaged in diverse livelihood activities in the world. Analogously, households in the study area were found engaged in various types of livelihood activities. The overview of these livelihood strategies practiced by sample households in the study area is presented in Table 16.

Not surprisingly, the result shows that crop farming is the main livelihood activity in the study area in which 98% of sample households were engaged. This suits the finding of Gecho *et al.* (2014) which shows that farming agriculture is a primary livelihood strategy in rural households of Ethiopia. It was also found that the mean annual income generated from crop farming was dominantly higher than other livelihood activities. Aside to crop farming, poultry was highly practiced as a source of household income which accounts for 38 % of the sample households. About 23% sample households were also practicing animal fattening and dairy to generate additional income. Perhaps, this small share may be due to the problem of fodder during the dry period. Derseh *et al*. (2016) confirmed that feed shortage and poor quality of available feeds are major constraints for livestock production in the highlands of Ethiopia. In addition, 16% and 14%

of respondents were engaged in daily laboring and trading cash crops, respectively which were very scarcely observed in the study area before. Some job opportunities could be amongst the tips of irrigation projects. However, the trend of engaging in fishing activity was found almost none which is 0.9%. This result is similar to the KIDP appraisal report which stated that fisheries activity in the project area is insignificant and limited to the *Koga* river (MacDonald, 2004).

Table 16:Major livelihood activities practiced in the study area

Livelihood activity	**Engaged Households**	**Mean generated income(birr)**
Crop farming	387 (97.97)	9239.54
Fattening	92(23.29)	5073.27
Dairying	91(23.04)	1468.18
Fishing	2(0.51)	1000.00
Poultry	150(38.07)	1225.00
Beekeeping	30(7.59)	1891.30
Daily labor	63(15.95)	2998.41
Employee	5(1.27)	5520.00
Petty trade	14(3.54)	2785.71
Merchant (cash crop)	56(14.18)	4364.29

Source: own survey **Note**: values in parentheses are percentage.

CHAPTER FIVE

WATER SHARING MECHANISMS AND FARMERS' PARTICIPATION IN COLLECTIVE IRRIGATION MANAGEMENT ACTIVITIES

5.1 Introduction

In this chapter, the results on water sharing mechanisms and farmer's participation in collective irrigation management activities is discussed. First of all, a descriptive summary for the basic demographic profile of irrigation user households is made. Here, the criteria how irrigator households were selected to be beneficiaries is also disclosed. Then, the results and discussions of water sharing mechanisms applied in the scheme are discussed. In the subsequent section of this chapter, farmers' participation in collective management activities and the factors that affect their level of participation are presented. Finally, the chapter ends with summarizing the basic findings.

5.2 Descriptive summary of irrigation user households

The demographic profile of irrigation user sample households showed in table 17 that majority of the respondents were males (68.6%). The average age was closely similar to the average of the whole sample population. These households have been lived on average for 37 years in their current respective residential kebele and they had 23 years of average farming experience, but it does not mean that they were practicing only irrigation farming. The average family size was 6 and the average years of attending formal education was 2 years. The average landholding in the scheme was 1.3 ha. This indicates the landholding in the scheme is smaller than the average household land holding of Ethiopia (CSA & WB, 2013).

Table 17:Descriptive summary on basic characteristics of irrigation user households'

Variable	Mean/percentage
Age (in years)	42.52
Total family size (in number)	6.004
Education level (in years)	2.027
Gender (1=male)	68.64
Total land size(ha)	1.304
Marital status(1=single)	12.27
Length of residence(years)	38.47
Farming experience	22.95

Source: own survey data

Season of irrigation in the KIDP

Farm households in the KIDP irrigate their plots from October through May. As it is shown in Table 18, the beneficiaries of the KIDP start irrigating as of late October up to early December. The majority (38%) of the surveyed beneficiaries start field watering in November. This simply indicates that it is a time in which most beneficiaries engage in irrigation-based agricultural tasks. On the other hand, based on the reaching timespan of crops, households end-up field irrigating from February up to May. However, the dam's control gate will be turned off at any time when adequate rain falls. The dam then keeps closed and accumulates water to the whole summer up to its maximum storage capacity. Seemingly, the result is consistent with the irrigation season practiced in the rest of Ethiopia. Holding the existence of agro-ecological variations, irrigation season in most parts of Ethiopia starts at the end or mid of spring when rainfall is off and dry season (*bega*) comes, and ends at the time of entrance of summer (*kiremt*) (table 18).

Table 18:Irrigation season in KIDP-% and frequency of respondents

Start-End month of irrigation	Freq.	Percent
December-April	21	9.55
December -February	3	1.36
December –March	16	7.27
December –May	6	2.73
November-April	84	38.18
November-March	42	19.09
November-May	15	6.82
October-April	17	7.73
October-March	3	1.36
October-May	13	5.90
Total	220	100.00

Source: own survey

5.3 The process of targeting irrigation beneficiary households in the KIDP

In a community that faces the effects of drought, poverty and food insecurity, irrigation agriculture is critically important. However, for various reasons, all households in and around the vicinity of irrigation projects could not be equally targeted to the project. According to the KIDP administration office, irrigator households in the KIDP were selected on the basis of how they were affected by the project. Groups of households who have been displaced and relocated because of the construction of the reservoir, inhabiting in the irrigation scheme and communities hosting relocatees were the identified affected groups by the project. These household groups were, therefore, considered in the process of beneficiary selection. According to the office, villagers in the command area were exclusively selected beneficiaries in the KIDP.

The descriptive result given in Table 19 strengthen the qualitative information taken from the key informant. About 84.1 percent of beneficiary respondents were directly targeted since they were geographically located in the command area even before the establishment of the project. The remaining 15 percent were relocated beneficiaries from the adjacent areas. This group of households is either being compensated in place of their land taken for construction or totally displaced from their residence to other *kebeles*.

Table 19:Irrigation beneficiary household selection criterion- frequency and % of respondents

Criteria of selecting irrigators	Freq.	Percent
Geographically located in the command area	185	84.09
Replaced land in place of land taken for construction	34	15.45
Investor	1	0.45
Total	220	100.00

Source: own calculation

The result suites to the findings of Gebre *et al.* (2008) who have argued that in most cases households reside in irrigation command areas are the direct targets, whereas in some cases based on the design and purpose of schemes, irrigation projects will apply different criteria to select beneficiary households. For example, according to the design of the scheme, all farmers that helped with scheme construction were allocated land within Bwanje valley irrigation scheme in Malawi (Nkhata, 2014).

5.4 Water Sharing Mechanism in the KIDP

5.4.1 Water allocation and distribution in the KIDP

Proper irrigation water allocation method helps producers to match water applied with crop needs. During our field visit, we found that the furrow irrigation system is the main and the only method of field water application in the KIDP. Ministry of Water Resources, (2006) has also confirmed that since it does not need a huge investment and has a low pumping cost, furrow irrigation is utilized in KIDP (Eriksson, 2012). However, this method is subjected to lower application efficiency, increased level of tail-water losses/run-off and accumulation of salinity between furrows.

Both the qualitative and quantitative survey results depicted that irrigation water was shared among users in a schedule set by 'water committees.' Each irrigation block has its own water controlling committee elected from among the beneficiaries and is responsible to formulate a schedule for water distribution. The schedule is prepared based on the calculation that the amount of water released/day to a block is divided for the plots within that block and then plot watering day length is figured. Here, the type of crops growing on the plot, nature of the soil, irrigation period and other critical factors were not considered in formulating the schedule. Based on this calculation, it was estimated that farmers could share water and irrigate their plot on average in every 13 days even when there is peak demand (Table 20). However, depending on the land size in the block and its location from the main canal, the time interval to get water ranges from 2-29 days. For example, the middle catchment beneficiaries irrigate their farmland relatively in short days (average of 11days) than the upper (average of 12days) and the lower (average of 16 days) catchments. This result is found consistent to the finding of Haile *et al.* (2003) whose study argued that within the area of irrigation, there may be land with a high, medium and low probability of irrigation. This probability depends to a larger extent on the location and level of the command area along the flood river, but also on the water sharing rules in place.

Table 20: Mean estimation of plot irrigating day length (overall and by location)

Length of days for irrigating	**Mean**	**Std. Err.**	**[95% Conf.**	**Interval]**
Upper catchment	12.03	.370	11.30	12.76
Middle catchment	10.87	.351	10.18	11.56
Lower catchment	15.69	.588	14.53	16.85
Grand mean of irrigating day length	13.05	.301	12.45	13.64

Source: own calculation

In general, the result clearly indicated that all crops in the KIDP had been irrigating using similar water allocation mechanism. This implies that farmers and other stakeholders did not consider the detail of factors during field water application. However, the decision of when and how much water to apply in farm field depends on detail of scientific factors such as crop water needs, crop sensitivity, crop peak water consumption, water availability in the soil, plant rooting depth and critical periods in the growing season (Ashley *et al.*, 1996; Brouwer *et al.*, 1989). For example, rice, banana, potato and sugarcane are very sensitive to water shortages. Crops like millet and sorghum, on the other hand, are only slightly sensitive to drought (Zwart & Bastiaanssen, 2004). Nonetheless, most irrigated farms continue to use less sophisticated methods to schedule irrigation water application (Schaible & Aillery, 2006). This is, therefore, less effective to closely match the available water with crop needs throughout the season which, in turn, influence the quantity and quality of production.

This seems consistent as we see the descriptive result given from Table 21. It shows that even though about 40 percent of respondents felt improvements in their production, equivalently, 40 percent thought as they could not see any positive or negative impacts of irrigation on their produce. In other words, 40 percent could not sense any special production difference to rain-fed production. The remaining 20 percent were even feeling as irrigation has negatively threats their production. However, this result does not indicate that irrigation had no contribution for those who felt as it has no positive/negative impact or negatively affects their production, rather it shows their feelings how much they were not suit to the water sharing system in the scheme.

5.4.2 General reflections from beneficiaries about the current water sharing mechanism in the KIDP

In line with the water sharing mechanism applied in the KIDP, respondents were asked some questions to put their feelings. Accordingly, more than 77 percent of respondents feel that irrigation water was fairly and equally distributed among beneficiaries, whereas 23 percent have complained about its fairness. About 53% of the surveyed households rated the effectiveness of water sharing mechanism in KIDP was good, while 28.6% responded as it was poor. As a general satisfaction level, majorities (61%) of respondents were satisfied by the delivered service, but 39 percent were not satisfied. As a result, about 78 percent of respondents were interested if the current water sharing mechanism is continued. However, 22 percent were not interested to continue with it and suggested another method of water allocation to be applied. In broad, these figures literally showed for the presence of water allocation related problems in the KIDP and hence further studies are recommended to identify problems and set most feasible water allocation mechanisms.

Table 21: Descriptive statistics of feelings of respondents on the current water sharing mechanism

Question	Freq.	percent
Do you think that there is equal water distribution among users?		
Yes	170	77.27
No	50	22.73
What do you feel about the impact of irrigation on your production?		
Positive	88	40.00
Negative	44	20.00
No impact	88	40.00
How do you evaluate the effectiveness of water sharing mechanism		
Very good	26	11.82
Good	118	53.64
Poor	63	28.64
Very poor	13	5.91
How much you are generally satisfied by the service		
Highly satisfied	37	16.82
Satisfied	97	44.09
Poorly satisfied	65	29.55
Unsatisfied	21	9.55
Are you happy to continue with the current water sharing mechanism?		
Yes	172	78.18
No	48	21.82

Source: own calculation

5.5 Households' Participation in Collective Irrigation Management Activities

Researchers (Fujiie *et al.*, 2005; Haile *et al.*, 2003; Ostrom, 2014) have underlined that beneficiaries' participation in collective irrigation management activities should not be overlooked since it is important for sustainable and efficient utilization of irrigation resources. As a result, this study has assessed how the KIDP irrigation users were participated in irrigation management activities by employing PCA.

The descriptive statistics in PCA shows that eight cases with no missing value were actually used in the principal components. Almost all variables have closely similar mean values. The least and largest value of each activity is also the same that indicates farmers' participation in each collective action vary from no involvement up to higher involvement (0-4) in the KIDP (Annex 5).

Eight principal components were extracted using Pearson correlations. Then, by applying the Kaiser criterion, two components with eigenvalues greater than 1 were retained. That is the information in 7 variables is represented by the two components. The initial number of factors used in the factor analysis was eight. Post-estimation test was conducted to ensure the proportion of variation in a variable explained by the other factors. It helps to assess how well this model explains most of the variation in those variables. As a result, seven variables with commonality value >0.5 were retained (annex 6, B) and one variable (attending training, i.e., ATRNG) was removed (annex 6, A). The PCA results are presented in Table 22 below.

The first principal component (PC hereafter) explains 56% of the total variation of farmers' participation in collective activities, with the second principal component explaining 16%. The two PCs together explained 72% of the variation in the data. Unlike PC2, all PC vectors in the first component are positive. This can be taken as evidence that PC1 represents the aggregate variations of farmers' participation in collective management activities. As a result, PC1 was retained and then used to generate the participation index (PI). The idea is consistent with Muchara *et al.* (2014) and (Manyong *et al.*, 2006) that the first retained component which accounts for a large percentage of the variance in the variables can be used alone without much loss of information. Following Fujiie *et al*. (2005), the PI is calculated as the sum of seven variables weighted by coefficients in the PC vector, after normalizing each variable by subtracting its average from individual observations and dividing these differences by standard deviation.

Table 22:Household's irrigation management participation index generation using PCA

	Extracted Principal component (PC)	
	1	**2**
Eigenvalues	3.92	1.11
% of explained proportion of Variance	55.95	15.71
% of explained Cumulative variance	55.95	71.66
Variables	**Factor loading**	
participate in canal maintenance (PCNLM)	0.1584	0.6689
Attending meetings (AMETING)	0.3605	0.4529
Contributing ideas in water related issues (IDEACONT)	0.3744	0.3269
Reporting unlawful water use (REPULWUSE)	0.4193	-0.2438
Reporting theft of irrigation infrastructure (REPTHFT)	0.408	-0.3345
Reporting and control water leakages /runoff (REPROFF)	0.4392	-0.233
reporting any infrastructure damages (REPDSTRN)	0.4118	-0.123

Source: own survey Rotation Method: Varimax with Kaiser Normalization; Note: Five-point Likert scale values are: 0 = not involved; 1=low involvement; 2=average; 3 = high; 4 = very high

The positive coefficient of a variable highly indicates farmer's participation in other activities. Hence, all variables in PC1 indicated that households were involved in various collective actions. On the contrary, the negative coefficient of a vector indicates a farmer (household) is likely to participate in a few other collective activates. The higher and lower coefficients mean that participating in an activity conveys more or less information about the other activity.

The first PC is dominated by participation in regulation and control activities. That means farmers were more involved in reporting resource wastage such as water leakages/runoff and infrastructural damages and controlling illegal activities like infrastructure theft and unlawful water use. This indicates that households are highly committed to keeping the abide rules and preventing free riders. A consistent finding was emerged by Ostrom (2000). The finding is that when the users of a common pool resource are organized themselves to devise and enforce some of their own basic rules, they tend to manage their resources more sustainably.

The second PC which is dominated by participation in labor-based activities (canal maintenance) followed by decision making actions (attending meetings and contributing ideas) reveals that the farmers were involved in other activities besides to activities in PC1. This is because most of the activities in communal irrigation management schemes are complementary in nature (Muchara *et al.*, 2014) and since some individuals are more willing than others to initiate reciprocity, the cooperation levels could vary from extremely high to extremely low across different settings (Ostrom, 2000).

In the PCA results, the high factor loading of water leakages/runoff further indicated water leakage and run off out of tertiary canals is a common problem. It is occurred either when diversion gates are not properly closed and damaged or when water is introduced into furrows. According to Schwankl *et al.* (2007), runoff begins when water reaches the lowest part, or end of the orchard, unless the end of the orchard is blocked with berms to keep the water in the orchard. The Possible solutions to prevent water leakage/runoff is, therefore, recruit stand by controller at the water gets and aware farmers about efficient irrigation water utilization.

In general, the result indicates that irrigating farmers were participating in few activities with varying level of participation so that they should be encouraged to participate equally in various collective activities because failure or success of a particular activity affects the performance of others. In line with this, Muchara *et al.* (2014) stated that despite the huge government investments made in the establishment of irrigation schemes, some are collapsed soon after their operation. One of the important factors for this problem is lack of beneficiaries' active participation in collective system management activities (Fujiie *et al.*, 2005; Haile *et al.*, 2003; Ostrom, 2014). Moreover, participatory approach is expected to deliver a number of positive outcomes and impacts like empowering farmers, better system maintenance and service, reducing cost of irrigation to the government, higher water productivity and profitable agriculture, and sustainable management of communal irrigation schemes (Kulkarni & Tyagi, 2012; Lin, 2003).

5.6 Determinants of Farmer's participation in Irrigation Management Activities

Even if irrigation beneficiary households were participating in limited collective management activities with different level of participation, various types of constraints would determine their active participation in the system. As a result, once assessing the farmers' participation in collective activities, the study expanded the idea into identifying the determinant factors that affect their participation.

To do so, a 2-limit Tobit regression model was employed because the response variable generated from PCA is right and left censored (Manyong *et al.*, 2006). Farmer participation index (PARTN_INDX) in collective irrigation management activities was, therefore, the dependent variable in the model. The scores were scaled from -5.08 to 3.22 and cannot fall outside of this range. Before interpreting the results, to ensure whether Tobit regression is correctly specified, post-estimation tests were done. Having a strong F-value (p=0.000), the model has a good fit to the data. Multicollinearity of the explanatory variables was tested using variance inflation factors (VIF), which were all below 10 with an average of 1.27. As a rule of thumb, if the VIF of a variable exceeds 10, there is a serious multicollinearity problem (Berhanu, 2005). To correct for heteroscedasticity, the robust standard errors were also estimated. Furthermore, normality was assessed by applying the Jarque-Bera test. As a result, the null hypothesis cannot be rejected that the model without predictors is as good as the model with the predictors; therefore, it is defendable to use the model. The result of Tobit regression model is presented in Table 23.

The empirical reviews and statistical results of this study show that determinant factors vary across communities with different environmental as well as socio-economic conditions. The regression result indicates that combinations of economic, institutional and social factors influence farmers' participation in the management activities of irrigation resources in the KIDP. Annual income gains from irrigation agriculture (INCMIRR), frequency of attending water-related meetings (MTNGPAR), trainings related to irrigation water management (TRNGPAR), farmer perception of rigid rule and regulations of the system (RGDRUL), credit (CREDIT) and extension (EXTENSION) services available for irrigators, and membership of water user's association (WUAM) were found to be statistically significant determinant factors of farmers' participation in collective activities.

Table 23:Determinants of farmer participation in collective irrigation management activities (Tobit results)

Variables	**Tobit regression**	
	Coef.	**Robust std. error**
Gender of household head (GENDER)	0.176	0.253
Age of household head (AGE)	-0.006	0.011
Family size (FAMSIZ)	0.065	0.066
Irrigable land size owned by hh (IRRLAND)	-0.207	0.278
Average annual income from irrigation agriculture (INCMIRR)	0.002*	0.001
Payment for irrigation management (PAYMNT)	0.290	0.509
Location of farm plot from the main canal (LOCDAM)	-0.075	0.158
Frequency of water-related meetings (MTNGPAR)	1.781***	0.350
Training in irrigation water management (TRNGPAR)	0.764***	0.279
Perception of water distribution equality (WDEQLTY)	0.216	0.276
Satisfaction with the work of committee (SONCMTT)	-0.341	0.299
Perceived rigid rule and regulations in the system (RGDRUL)	0.361*	0.228
Perceived participatory approach in the system (PARTAPP)	-0.102	0.308
Conflict on water sharing (CFLCT)	0.058	0.260
Education level (EDUYRS)	0.055	0.038
Access to credit (CREDIT)	0.334***	0.101
Access to extension (EXTENSION)	0.514**	0.258
Membership of water user association (WUAM)	0.504*	0.354
_cons	-3.059***	0.899
/sigma	1.520	0.070

F (18,201)	9.600	Uncensored observations	216
Prob>F	0.000***	Left censored observations	1(Minimum ≤ -5.08)
Pseudo R2	0.131	Right censored observations	3(Maximum ≥3.22)

Note: *, ** & *** denote significance at the 10%, 5% and 1% levels, respectively.

Source: own survey

The result indicates that participation in collective actions is influenced by the average annual income gain from irrigation agriculture. Indeed, this is meaningful because a farmer who gains more income from irrigation agriculture is more eager to participate in management activities than those whose gain is low. Since the main purpose of irrigation is profit maximization, beneficiaries' willingness to manage irrigation resources will be decreased if it does not increase their income. This is consistent with the study of Muchara *et al.* (2014) whose finding revealed that income generated in irrigation farming can be one of the incentives for farmers to participate in irrigation activities.

Another economic factor which significantly affects farmer participation was the availability of credit service for irrigators. It indicates that farmers who have access to credit service were more willing to participate in collective management activities. According to Venot *et al.* (2012), one of the main constraints preventing smallholder farmers from cultivating more land and adopting irrigation technologies and affect the will of participation in management activities is the cost of inputs. Hence, to cover the costs, irrigator households are more likely to apply to loan services than non-irrigator households (Hagos et al., 2017). This reveals that they could be discouraged to participate in management activities if they are not allowed for that loan. The data of this study indicated that equivalent to non-irrigators (66.9%), about 66.4% of irrigators in the KIDP had no access to credit loans which most likely affects their participation (see section 4.2.2). This suggests the importance of strengthening local microfinance institutions to address the demand for credit services, which might improve farmers' technology adoption habits, which requires farmer's participation in irrigation activities.

As can be seen from regression results, most determinants of participation in management activities in the KIDP were institutional related variables. One of them is the frequency of attending water-related meetings. It indicates since the meeting is a channel through which farmers could get updated information about what a system requires to be done, irrigators more likely to participate in collective actions if the system has regular meetings. In addition, training related to irrigation water management has influenced farmers' participation. Beneficiaries having a piece of irrigation management training were more likely to actively participate in management activities. This makes economic sense, as farmers could get more capacity building training, their demand to adopt technologies for maximizing their production increases and hence they will invest more effort to manage their resources for this achievement. Moreover, meeting and training are keys to disseminate knowledge and information which might result in cooperation among members. This fits the finding of Nakano &Kajisa (2011) who noted that the adoption of modern varieties and resource management are highly associated with training in both rain-fed and irrigated plots. Furthermore, the beneficiaries' perception of rules and regulations of the system determine their participation in collective actions. Water users who perceive the abide rules and regulations are not rigid were probably more participants than those who perceive the system use rigid rules and regulations. This could occur when either beneficiary has no detail awareness of rule and regulations or when rules are set without people's participation and agreement. These findings highlight the importance of regular meetings and training to improve farmer participation in collective irrigation system management. It is also indicated that since rules and regulations benefit irrigators themselves, it should be explicitly agreed upon and practiced. Because social norm and rule, especially in a setting where there is communication between the parties, can work as well at generating cooperative behavior than the externally imposed set of rules (Ostrom, 2014).

The estimated coefficient for the access to extension service positively affects farmers' participation in collective irrigation management. As farmers could get good access to professional advice and consultation (agricultural extension service) about how to advance their resource management skill, then more effort is required by the farmer. This is the reason farmers accessed to extension service were more likely to take part in irrigation management activities in the KIDP. Consistently, Ammani *et al.* (2011) confirmed that achieving the goal of increasing agricultural production through harnessing of national irrigation potentials mostly depend on agricultural extension services. However, about 32.7% sample irrigators in the KIDP had no access to extension services. This indicates farmers are still practicing their former traditional knowledge which might not guarantee them to efficiently utilize this modern irrigation technology.

The result indicated membership of water users' association significantly affects farmer participation in management activities. It indicates active members of WUA were more likely to participate in collective actions than non-members. This implies that membership of farmers' association or cooperative society is preferable to manage resources rendered to them.

On the other hand, unlike Muchara *et al.* (2014), average irrigated land size, education level and position of the plot from the main canal were not found to be statistically significant influencing factors of collective participation in the KIDP.

5.7 Chapter Summary

The qualitative and statistical results indicated that irrigation beneficiary households were selected from those groups of households who have been displaced and relocated because of the construction of the reservoir, inhabiting in the command area and communities hosting relocates. Irrigation water was shared among irrigators in a schedule set by 'water committees'. Based on the calculation figured by the committee, it was estimated that a plot was irrigated on average in every 13 days. In general, the result clearly indicated that all crops in the KIDP had been irrigating in a similar water allocation mechanism.

The PCA result indicated that farmers were mainly participated in regulation and control irrigation management activities. Specifically, farmers were more involved in reporting and controlling resource wastage such as water leakages/runoff and infrastructural damages and controlling illegal activities such as infrastructure theft and unlawful water use. The regression result indicates that combinations of economic, institutional and social factors influence farmers' participation in collective irrigation management activities.

CHAPTER SIX

DETERMINANTS OF FARMERS' CROP CHOICE DECISION UNDER IRRIGATING AGRICULTURE

6.1 Introduction

The sixth chapter presents a brief review of the results and discussions of the second specific objective of the study. The chapter looks at the basic characteristics of households with different crop choice decisions. Besides, it presents the main crops cultivated under the KIDP and grouped them in to six major crop categories. The chapter goes on discussing the determinants of farmers' crop choice decision in irrigation agriculture in each crop category. Then, it is closed by summing up main findings of the objective.

6.2 Characteristics of households with different crop choice decisions

According to the descriptive analysis, some variations were observed in the six crop categories in terms of households' demographic, social and economic characteristics. The households have differed to some extent in their age, family size, farming experience, land holding size, the time taken to grow a crop, their perception on crop marketability and crop resilience to climate change, access to input supply, expertise advise and access to market (Table 24 and 25).

The mean values of continuous variables in all crop categories were compared using F-test. Accordingly, out of 7 continuous variables, households were found significantly different in 5 of them in the six crop categories (Table 24). The statistics revealed that those farmers who were engaged in producing cereals, vegetables and cash crops in combination had relatively better farming experience (25.9 years) and farm holding size (1.5 ha) than others. The mean age for this group of sample households was also greater than others. Though there was a significant difference among groups, the types of crops that were chosen by the sample households to grow in the command area took an average of 4.2 months to reach.

Table 24:Descriptive statistics for continuous explanatory variables

Variables	**Crop choice categories (mean)**							
	CO	VO	C-V	V-Ccr	C-Ccr	C-V-Ccr	Total	F-value
Age in years	42.9	35.5	39.3	41	44	44.4	41.7	6.8***
Family size	5.2	4.5	5.9	6.4	5.9	6.3	5.6	7.5***
Education in years	1.3	2.2	2	2.4	0.8	2.3	1.6	0.79
Farming experience	20	11.4	20.6	20	21.4	25.9	22.9	13.8***
Input cost	9000	2812	14665	10220	6722	10386	11052	2.67
Crop growth period	5.2	4.5	4.4	4.2	3.88	4.1	4.2	30.6***
Land holding size	1.1	0.7	1.2	1.3	0.9	1.5	1.3	13.8***

Note: CO, VO, C&V, V-Ccr, C-Ccr & C-V-Ccr stands for Cereal only, vegetable only, cereal and vegetable, vegetable and cash crop, cereal and cash crop, and cereal, vegetable and cash crop producers, respectively. ******* stands for significant at 1%.

Source: own survey.

In addition, a chi-square test was employed to examine statistical differences between the discrete variables of households regarding their crop choice. Accordingly, statistically significant differences were observed in 5 variables among the 12 discrete variables (Table 25). The variables are the household perception on crop marketability and crop resilience to climate change, and access to input supply, expert advice and access to the market. About 52.3 percent of sample households believed that the crops they choose to produce are medium marketable. On the other hand, 58.6 percent perceives that the crops they have been cultivating were not resilient to climate change. It is also indicated that there was a statistically significant difference in agricultural input supply, access to expert's advice regarding crop production and access to the market. Having differences in categories, we found that about 56.4 percent of respondents had no input supply. About 50 percent and 64 percent had access to market and expert advice, respectively.

Table 25: Descriptive analytical results for discrete explanatory variables

Variables	Response	Crop choice categories (%)							
		CO	VO	C-V	V-Ccr	C-Ccr	C-V-Ccr	Total	x^2
Gender of the household head	Male	1.8	4.5	14.5	2.7	6.4	35	68.6	4.4
	Female	1.8	0.5	7.7	1.8	1.8	17.7	31.4	
High Yield expectancy	Yes	6.8	5	21.8	4.5	8.2	52.7	97.7	2.1
	No	0.5	0	0.5	0	0	1.4	2.3	
Crop marketability	High	1.4	2.3	4.5	0.9	0.9	8.6	18.6	17.9^{**}
	Medium	5.5	2.3	13.2	1.8	3.2	26.4	52.3	
	Low	0.5	0.5	4.5	1.8	4.1	17.7	29	
Crop home consumption	High	5.5	1.8	11.8	2.3	6.4	29.5	57.3	12.4
	Medium	1.8	2.7	6.4	1.4	1.8	15	29	
	Low	0	0.5	4.1	0.9	0	8.2	13.6	
Input supply	Yes	6.4	3.6	14	2.3	5.9	24.1	43.6	15.8^{***}
	No	0.9	1.4	8.2	2.3	2.3	28.6	56.4	
Crop water need	High	0.5	1.8	5.9	0.9	2.7	19.5	31.4	10
	Medium	6.4	2.7	13.6	2.7	4.5	29	59	
	Low	0.5	0.5	2.7	0.9	0.9	4.1	9.5	
Crop resilience to climate change	Yes	5.9	9.5	15.9	1.8	5	25.9	41.4	14.9^{***}
	No	1.4	0.9	6.4	2.7	3.2	26.8	58.6	
Expertise advise	Yes	1.8	1.4	10.9	2.7	5.5	41.8	64	33.7^{***}
	No	5.5	3.6	11.4	1.8	2.7	10.9	35.9	
Access to market	yes	5.9	2.3	13.2	2.3	4.5	21.8	50	11.4^{**}
	No	1.4	2.3	9.1	2.3	4.5	30.9	50	
Irrigation water supply	High	0	0	3.6	0	1.4	7.3	12.3	10.9
	medium	6.8	3.6	12.7	3.2	5	33.6	65	
	Low	0.5	1.4	5.9	1.4	1.8	11.8	22.7	

Note: CO, VO, C&V, V&Ccr, C&Ccr & C, V&Ccr stands for Cereal only, vegetable only, cereal and vegetable, vegetable and cash crop, cereal and cash crop, and cereal, vegetable and cash crop producers, respectively. ***** &****, stands for significant at 1% & 5%.

Source: own survey

6.3 Types of crops produced by irrigators in the KIDP

Before we entered into the main phase of data collection, first, we have identified the types of common crops produced under the *Koga* irrigation development project. It was done based on secondary data sources and through the pilot test questionnaire. As a result, the main identified crops grown in the command area using irrigation water were wheat, *teff*, millet, barley, maize, cabbage, potato, tomato, green paper, garlic, onion, coffee, *khat* and eucalyptus tree (note that irrigation was used for less than one-year eucalyptus plant and seedling production) (Figure 7).

Figure 7: Some types of crops grown under Koga Irrigation Development project

Source: Own field observation

The data indicated that wheat (75%), maize (70%) and onion (67%) were found to be one up to three highly cultivating crops in the study area, whereas *chat* was cultivated by few households (Table 26). Consistently, the KIDP report before one year of this survey indicated that wheat was the first in terms of production and profitability followed by potato and onion (Annex 7).

Table 26: Types of crops produced at the study area

Crop type		**Mean percentage of producers**	**Std. Dev.**
Cereals	*Wheat*	.750	.434
	Teff	.186	.390
	Millet	.214	.410
	Barley	.233	.423
	Maize	.700	.459
Vegetables	*Ethiopian cabbage*	.109	.312
	Head cabbage	.383	.487
	Garlic	.251	.435
	Onion	.676	.469
	Potato	.522	.501
	Tomato	.136	.344
	Green Pepper	.195	.397
Cash crops	*Coffee*	.314	.465
	Chat	.045	.208
	Eucalyptus tree	.582	.494

Source: own survey

As shown in the table below, the lists of crops were categorized into six groups for ease of analysis (Table 27). These categories were used to clearly show the type of crops chosen by a household. In the six crop choice options, a household has only one probability of selection and these categories were used in MNL model estimation. Differently, the first three groups (cereal crop, vegetable, and cash crop) in the table are used simply to indicate the number of households engaged in producing the types of crops so that double/triple counting is expected in the calculation. As it is indicated below, the majority of the sample households (91%) were producing cereal crops. About 84 percent and 65 percent were also engaged in vegetable and cash crop production, respectively.

Table 27: Types of crops chosen by sampled households to produce in the KIDP

Crop choice categories	**Number of households**	
	Freq.	Percentage
Cereal crop	199	90.7
Vegetable	185	84.5
Cash crop	144	65.4
Cereal crop only	16	7.3
Vegetable only	11	5
Cereal and vegetable	49	22.3
Cereal and cash crop	18	8.2
Vegetable and cash crop	10	4.5
Cereal, vegetable and cash crop	116	52.7
Total	220	100

Source: own survey

Regarding the six exclusive groups, the statistics indicated that a significant number of sample households found engaged in producing cereal crops and vegetables separately without combining other crops that were 7.3 percent and 5 percent, respectively, whereas 87.7 percent households have been producing diversified crops. About 22.3 percent and 8.2 percent sample households produce cereals with vegetables and cereals with cash crops, respectively. About 4.5 percent of households were producing vegetables with cash crops together, but without including cereals. Moreover, above half of the sample households (52.7%) were producing cereals both with vegetable and cash crops in combination.

The descriptive statistics revealed that cereal crop production such as wheat, maize and barley was Priorly practiced in the study area. Consistent with the findings by Alemayehu *et al.* (2011), wheat and maize found the major cereals grown in the command area. Since these crops were produced in surplus, farmers sell it when they require cash to purchase goods, they couldn't otherwise make themselves (like industrial products). On the other hand, the non-food crops help farmers to fill the income gap that the staple crops unable to do. In this regard, it is indicated that the majority of farmers have been cultivating cash crops with cereals and vegetables together. This indicates that farmers in the *Koga* irrigation development project have been practicing diversified crop cultivation. Merely cereal producer households were found small. According to De Sousa *et al.* (2017), irrigation opened opportunities to diversify crop cultivation and crop diversification is one way of improving the profitability of irrigation schemes. Even if cereal crop production is predominant, vegetable production was also found considerably high in the study area. This suits the finding of Lamont *et al.* (2001) which confirms that access to irrigation increases vegetable cultivation because vegetable crops require irrigation to minimize plant stress.

6.4 Multinomial Logit (MNL) Model Results and Discussions

6.4.1 Factors determining farmers crop choice decision in the KIDP

Based on the theoretical background and review of related literature, the multinomial logit model was specified to identify the factors that influence farmers' crop choice decision under irrigation agriculture. The dependent variable is the category of crops that the farmers choose to produce in the KIDP. The model was undertaken by normalizing one category, which is referred to as the ‘‘reference state,’’ or the ‘‘base outcome.’’ In this analysis, the first category (cereal-only) is the reference state and effect coefficient for each crop choice category was estimated with respect to producing only cereal crops.

The model was tested for multicollinearity among explanatory variables using the variance inflation factor (VIF). The VIF values for all variables were less than 10 (their mean was 1.4), which indicate that multicollinearity is not a serious problem in this model. Moreover, the model was run and tested for the validity of the independence of the irrelevant alternatives (IIA) assumptions by using the Hausman test for IIA. The test suggesting that the multinomial logit (MNL) specification is appropriate to model households' crop choice. Furthermore, maximum likelihood parameter estimation indicated that the likelihood ratio (x^2) was highly significant ($P<0.00001$), suggesting the model has a strong explanatory power. The pseudo R^2 value (0.3808) also confirmed that all the slope coefficients are not equal to zero which means the explanatory variables are collectively significant in explaining the crop choice by cereal-only crop producers in the study area. The results of the maximum likelihood estimates are presented in Table 28.

Table 28: Results of the estimated multinomial logit model for factors influencing crop choice decision

Variables	Vegetable only	Crop choice categories: Cereal & vegetable	Vegetable & cash crop	Cereal & cash crop	Cereal, vegetable & cash crop
Age of household head	.12(.11)	-.03(.05)	-.00(.06)	.05(.06)	.00(.05)
Education	.25(.35)	.16(.17)	.29**(.21)	-.02(.25)	.29*(.18)
Farming experience	.004***(.15)	-.01(.05)	-.01(.06)	-.004(.05)	.02(.05)
Input cost	.004***(.00)	.0001*(.00)	.001(.00)	-.0001(.00)	.001(.00)
Length of crop maturity period	-.95(.79)	-1.41***(.50)	-1.77***(.62)	-2.48***(.73)	-1.85***(.51)
Land holding size	-8.70**(3.9)	-.39(.77)	.35(.93)	-2.90***(1.2)	.41(.76)
Gender of household head	1.40(2.24)	-1.11(.90)	-1.3(1.1)	-.58(1.2)	-1.23(.89)
High Yield expectancy	8.81(1286)	5.85**(2.87)	21.22(2272)	20.01(112)	6.27**(2.7)
Crop marketability	-4.50***(1.8)	-.84(.71)	-.52(.87)	1.03(.85)	-.54(.70)
Crop in-home consumption	2.31**(1.2)	1.47*(.79)	1.46*(.91)	-.64(1.1)	1.72**(.79)
Input supply	3.00(2.35)	-.58(1.1)	-.52(1.34)	1.18(1.4)	-.55(1.11)
Crop water consumption	-5.96**(2.6)	-.48(.75)	.074(.92)	-.45(.89)	-.79(.74)
Expertise advise	-1.27(1.5)	.75(.82)	.89(1.03)	.72(1.01)	1.82**(.82)
Access to market	4.29**(2.8)	2.04(1.26)	1.89(1.5)	2.41*(1.4)	2.41**(1.2)
Irrigation water supply	5.58***(2.3)	.57(.81)	.86(1.01)	.33(.96)	-.11(.79)
_cons	9.90(7.6)	9.80**(4.3)	6.36(5.3)	11.63**(5.3)	10.43**(4.3)
Base Category = Cereal only Log likelihood = -184.93939 Number of obs. = 220		LR chi2 = 227.50*** Pseudo-R^2 = 0.3808			

Source: own data analysis

The parameter estimates of the MNL give only the direction of the effect of explanatory variables on the dependent variable, but the estimates do not represent the actual magnitude of change or probabilities (W. Greene, 2003). As contained in the above table, it is shown that the set of significant explanatory variables varies across the choice options in terms of the levels of significance and signs. The result indicates that among 15 hypothesized explanatory variables 12 were found significant determinants of crop choices. The positive/negative sign implies that the probability of choosing a crop category tends to increase or decrease with the significant variables relative to the base outcome. It is, however, difficult to give an economic interpretation of this model other than a flexible approximation to a general functional form (Ayele *et al.*, 2015). Thus, the marginal effect measures the expected change in the probability of a given choice that has been made in relation to the unit change in the explanatory variable (Deressa *et al.*, 2009; Gecho *et al.*, 2014). The plausible implication and marginal effects of the significant explanatory variables on the households' crop choice are presented in Table 29. In all cases, the estimated coefficients should be compared with the base category of cereal-only.

Table 29: Marginal effects after multinomial logit

Variable	**y=CO** =0.013	**y=VO** =2.340e-06	**y=CV** =.264	**y=VCcr** =.054	**y=CCcr** =.009	**y=CVCcr** =.659
	dy/dx	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*
Age in years	.001	3.01e-07	-.007	.002	.001	.006
Education in years	-.003	-5.98e-07	-.024	.002	-.003	.027
Farming experience	-.002	-7.91e-07	-.002	-.001	-.002	.004
Input cost	-1.002	7.63e-10	.001	-1.41e-06	-1.45e-06	-9.56e-06
Length of growing period	.020	1.79e-06	-.079	-.003	-.008	-.091
Land holding size	-.002	-.00002	-.145	.011	-.030	.167
Gender of household head	.013	4.37e-06	.018	-.010	.014	-.035
High yield expectancy	-.130	.051	.023	.047	.084	.074
Crop marketability	.008	-9.14e-06	-.065	.004	.016	.037
crop home consumption	-.02	1.66e-06	-.032	-.007	-.022	.083
input supply	.006	.001	-.014	.001	.017	-.011
Crop water consumption	.009	-.001	.045	.039	.002	-.095
Expertise advise	-.024	-.001	-.187	-.030	-.007	.249
Access to market	.036	5.57e-06	.054	.019	.002	.108
Irrigation water supply	-.004	.001	.077	.032	.001	-.106

Note: CO, VO, CV, VCcr, CCcr & CVCcr stands for Cereal only, vegetable only, cereal-vegetable, vegetable-cash crop, cereal-cash crop, and cereal-vegetable-cash crop producers, respectively.
Source: own survey calculation

The model result indicates that education, farming experience, input cost, length of growing period, high yield expectancy, crop marketability, crop in-home consumption, crop water consumption, expert advice, irrigation water supply and access to market were found to be determining factors of farmers' decision on crop choices. However, note that the magnitude effect of the significant variables is not similar for all crop choice options.

The MNL result shows that education had a significant and positive influence on farmers' decision in selecting vegetable with cash crop and cereal with both vegetable and cash crop combinations at 5% and 1% significance level, respectively. A unit increase in the number of years spent in formal education would result in a 0.2% increase in the probability of producing vegetables with cash crops and a 2.7% increase in cultivating cereals-vegetables-cash crops in combination. This implies that with an increased level of education, the probability of incorporating crops such as vegetables and cash crops with cereals is more likely greater as compared to producing only cereal crops. Moreover, the marginal values of education for the two categories are positive indicating that education has a positive influence on farmers' decision to incorporate high-value crops such as vegetable and cash crops (coffee, *khat* and eucalyptus tree). This result suites to the findings by Ayele *et al.* (2015) and Ojo *et al.* (2013) which confirms that farmers' education has positive and significant impact on farmers decision to choose diversified crops such as cereals in combination with high-value crops, for example, cash crops and vegetables under irrigation agriculture (Abro, 2012). The farming experience was only significant for vegetable-only crop choice selection. Thus, those farmers with larger farming experience were less likely to cultivate only vegetable crops under irrigation agriculture. The coefficient on land holding size was significant and negative for vegetable-only and cereal-cash crop choices at 5% and 1% significance level, respectively. This indicates that when there is a unit increase of landholding size, the priority of selecting the two crop choice options is decreased. For example, the statistics indicate a unit increase in land holding size results in a 3% decrease of choosing cereals with cash crops.

Input cost was found to be significant and positive for vegetable-only and cereals combined with vegetable chooser farmers at 1% and 10% significance level, respectively. This represents the elasticity choice for 1-birr additional cost on input will result in an increase in the probability of cultivating vegetable-only and cereal with vegetables. In different ways, Ayele *et al.* (2015) found out that production input cost decreasing the choice of cereals - pulses – vegetables. The length of crop growing period (crop reach period) was found significantly and negatively influencing the probability of selecting all crop choice categories except vegetable-only choice. The marginal effect value indicated that a unit increase in the length of crop growing period decreases the elasticity of choosing a cereals-vegetable, vegetable-cash crop, cereal-cash crop and cereal-vegetable-cash crop combinations in 7.9%, 0.3%, 0.8%, and 9%, respectively. This result reveals that farmers were less likely to choose long time taking crops under irrigating agriculture, perhaps, this is due to the interest of farmers to produce quickly reaching crops twice or three times in a season.

Those farmers who expected high yield were priorly cultivate cereal crops combined with vegetables and cereal crops combined with vegetables with cash crops. This result indicates that when the households expect high yield from their farm, they probably choose cereal crops with vegetable in 2.3% and cereal crops with vegetable with cash crops in 7.4% as compared to the base outcome. This suggests that farmers are more likely intended to diversify their cropping system when they wish to have a high amount of yield. The finding by Greig (2009) supports this result which argues the view that 'the yield of the crop generally good' is appeared more influential in the decision-making process of crop choice. In a different way, Rahman (2008) found that yield expectation has negatively influenced crop diversification. This is, of course, logically convincing because farmers might not diversify their crops when their demand is to have high yield from a single crop item.

Crop marketability and crop in-home consumption (utilization) were found significant determinants of crop choice. Crop marketability was significant for vegetable-only selection and it was negative that indicates those farmers who perceive as a crop is low marketable less likely to choose to cultivate vegetables-only. This indicates that the financial context of the farm is of greater importance for this farmer type. This is not surprising given that the primary aim of irrigational farming is to make a profit (Greig, 2009). Crop in-home consumption was found to be positive and significant for vegetable-only and cereals combined with both vegetable and cash crop chooser farmers, whereas negative for those who were combining cereal with vegetable and vegetables with cash crops. This result suggests that a change in crop in-home utilization from high, medium to low results in decreasing the probability of choosing a cereal with vegetable and vegetable with cash crop combinations by 3.2% and 0.7%, respectively. On the other hand, when crops are highly consumed in home, the farmers most likely choose to produce vegetables-only and cereals combined with both vegetables and cash crops in irrigation agriculture.

A clear relationship between crop water consumption and adequate irrigation water supply and crop choice decision has emerged. Crop water consumption had a significant and negative impact on the choice of vegetable-only at 5% significance level. This means when the crop water consumption is high the likelihood of choosing only vegetable crops will decrease. Similarly, Rahman (2008) and Ayele *et al.* (2015) confirmed that crop water need negatively influence crop diversification because farmers will drop crops that need more water. On the other hand, the adequate water supply had a positive and significant impact at 1% significance level. This implies that the change of irrigation water supply from low to high will most likely increase the selection of vegetable-only crop category. Analogously, Greig (2009) found out that the availability of water is positively significant in crop choice decision-making process because so as to earn a good yield, farmers require a continuous supply of water for the irrigation of land.

As expected, access to expert advice has a positive and significant impact on cultivating diversified crops that is cereals-vegetable-cash crop combination. It is found that having access to pieces of advice from experts about crop production more likely increase the probability of producing diversified crops by 25%. The availability of market access was also found clearly fundamental to crop choice. It was found to be significant and positive for vegetable-only, cereal-cash crop and cereal-vegetable-cash crop combinations. For instance, the elasticity of selecting cereal with cash crop and cereals with both vegetables and cash crops was increasing at 0.2% and 10.8%, respectively. This result is supported by different authors. For example, Rahman (2008), Ojo (2013) and Mitiku *et al*. (2015) found out that market access has positively influencing crop diversification.

6.5 Chapter Summary

The result indicated that wheat, maize and onion were the first three highly cultivating crops in the KIDP, whereas *chat* was less cultivated. The statistics indicated that a significant number of sample households found engaged in producing cereal crops and vegetables separately without combining other crops, while 87.7 percent households have been producing diversified crops. While irrigation enhances the opportunity of crop choice decisions, there are a serious of household, institutional, social and economic factors that affect farmers' decisions to select crops. According to the MNL model estimation, education of a household head, farming experience, input cost, length of crop growing period, yield expectancy, crop marketability, crop in-home utilization, crop water consumption, expert advice, adequacy of irrigation water supply and access to market were found to be determining factors of farmers' crop choice decisions in the KIDP. However, the magnitude effect of these variables was not similar for all crop choice options. Among others, the length of crop growing period and crop in-home utilization were the most important determining factors because they influence almost three-quarters of the cases.

CHAPTER SEVEN

IMPACT OF IRRIGATION ON HOUSEHOLDS' FOOD SECURITY AND POVERTY REDUCTION

7.1 Introduction

This chapter presents the results and discussions of two the subsequent objectives of the study. The first section of this chapter deals with the impact of irrigation on households' food security. The section goes on overviewing the descriptive summary of irrigator and non-irrigator sample households. In addition, the households' multidimensional food insecurity analysis of the study area is presented. Having argued on these parts, this section of the chapter addresses the impact of irrigation on household's multidimensional food security and annual income. In the second section of the chapter, the impact of irrigation on household's multidimensional poverty reduction is presented. Under this part, the multidimensional poverty situation of the study area is analyzed. Besides, it addresses the impact of irrigation on household's poverty reduction. It also differentiates the level of households' poverty reduction across the three irrigation reaches. Presenting opinions and perceptions of households on the contribution of KIDP for poverty reduction is also part of this section.

7.2 Does Irrigation Improve Households' Food Security?[7]

7.2.1 Summary statistics of irrigator and non-irrigator households

Here, we present a summary of some of the most important variables included in the PSM model. The descriptive results indicated that there was a statistically significant difference in socio-economic characteristics between irrigator and non-irrigator households. Except for the gender variable, differences are noticed for all other variables. The significant difference in average age between irrigators and non-irrigators was small. Examining the educational status, the result shows that there is a statistically significant education level difference between irrigator and non-irrigator households. The significant difference is also observed in private land holding size between the

[7] "**Does Irrigation Improve Households' Food Security?"** is a submitted manuscript for publication to the *journal of Global Food Security,* Elsevier and is under review.

two groups. Furthermore, the descriptive result noted that the mean annual income among irrigators and non-irrigators was statistically different. But the average years of farming experience for the two groups was almost similar. Also, irrigators were found to have better access to extension service than their counterparts (for details see Table 30 below).

Table 30:Summary statistics of selected continuous and dummy variables used in estimating the treatment effect of irrigation on food security

Variable definition	**All sample hh (N=395)**	**Non-irrigators (N=175)**		**Irrigators (N=220)**		**T-test/ x^2 test**
	Mean	Mean	st. Dev.	Mean	st. Dev.	
Age of household(years)	41.7	40.5	13.30	42.7	11.66	-1.776*
Family size(number)	5.6	5.2	1.99	6	1.96	-4.086***
Education (in years)	1.6	1.1	2.44	2.0	2.71	-3.527***
Private land size(hectare)	0.9	0.8	0.53	1.1	0.61	-4.948***
Farming experience (years)	21.9	20.6	13.23	22.9	12.84	-1.799*
Annual income (birr)	12913	9840	7690.3	15357.7	14082.4	-4.659***
Household head Sex (1=male)	267(67.6)	116(29.4)		151(38.2)		0.246
Access to extension service(1=yes)	295(74.7)	125(31.6)		170(43.1)		1.761*

Note: ***, ** & *=significant at 1%, 5% and10% respectively; values in parenthesis are percentage
Source: own household survey

7.2.2 Households' multidimensional food security score and prevalence analysis

The multidimensional household food security score is calculated by summing the codes for each frequency-of-occurrence question. It is a continuous value in the measurement of food (in)security of the household in a recall period of one month (30 days). The maximum score for a household is 96 (if the household response to all twenty-four questions is "4"), and the minimum score is 24 (if the household responded "1" to all occurrence questions). However, unlike HFIAS, a higher or lower score does not indicate the food (in)security experience of a household. Because the meaning of values from "1" to "4" vary according to the context of the question. The two-sample *t*-test of multidimensional food security score in the table below revealed that there is no significant difference among irrigators and non-irrigators.

Table 31:Two-sample t test of multidimensional food security score with equal variances

Group	Obs	Mean	Std. Dev.
Irrigator	220	38.22727	4.743001
Non-irrigator	175	38.59429	3.701657
Combined	395	38.38987	4.311465
diff		.367013	

diff = mean (0) - mean (1) t = 0.8401

Ho: diff = 0 degree s of freedom = 393

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0

Pr (T < t) = 0.7993 Pr (T > t) = 0.4014 Pr (T > t) = 0.2007

Source: own calculation

As indicated in Table 32 below, the multidimensional food security indicator categorizes households into levels of “food secure,” “mildly food insecure,” “moderately food insecure” and “severely food insecure.” Households are categorized as severely food insecure as they experience severe conditions more frequently. On the contrary, a food secure household does not experience severe conditions (Coates *et al.*, 2007).

Table 32:Multidimensional household food insecurity prevalence-freq. and percentage

MFI category	All study households	Irrigator	Non-irrigator
Food secure	49 (12.41)	36 (9)	13(3.4)
Mildly food insecure	289(73.16)	141(35.7)	148(37.5)
Moderately food insecure	50(12.66)	37(9.4)	13(3.3)
Severely food insecure	7(1.77)	6(1.52)	1(0.25)
Total	395(100)	220(55.69)	175(44.31)

Note: values in parentheses are percentages. Pearson chi2(3) =21.2055 Pr = 0.000

Source: own field survey

The result indicates, the prevalence of mildly food insecurity was higher in the study area which accounts for 73 percent of the total sample households, while 1.8 percent were severely food insecure. The rest 12.7 percent and 12.4 percent of the respondents were moderately food insecure and food secure, respectively. Of the total mildly food insecure sample households, 35.7 percent and 37.5 percent were irrigators and non-irrigators, respectively. Among the total food secured households, 9 percent were irrigators and 3 percent were non-irrigators. The MFI prevalence of moderately and severely food insecurity in irrigation users and non-users were 9.4% and 3.3%, and 1.52% and 0.25%, respectively. This implies that irrigator households were less mildly food insecure and more food secure than non-irrigators. On the other hand, non-irrigator households were less moderately and severely food insecure than irrigators.

As per Maxwell *et al.* (2013) classification, food secure and mildly food insecure households are further classified "food secure", whereas moderately food insecure and severely food insecure households are categorized "food insecure." Based on this classification, a majority (85.6%) of the sampled households constituted under the general category of "food secure", while about 14.4% households were found under the category of "food insecure" (Table 33). Specifically, of the food secured households, 45% and 40.6% were irrigators and non-irrigators, respectively. On the other hand, 10.9% irrigators and 3.5% non-irrigators were food insecure.

Table 33:Households food security status at the study area

Food security category	**All sample hhs**	**Irrigator hhs**	**Non-irrigator hhs**
Food secure	338(85.6)	177(44.8)	161(40.8)
Food insecure	57(14.4)	43(10.9)	14(3.5)
Total	395(100)	220(55.69)	175(44.31)

Note: values in parentheses are percentages. Pearson chi2(1) =10.5218 Pr = 0.001
Source: own field survey

Generally, the MFI result could be understood in such a way that food insecurity in the study area is still a problem, but it seems lesser as compared to the food insecurity trend in different parts of the country. This result is not far different from previous studies. Fayera (2016) and Devereux &Sussex (2000) argued that the food security situation in rural parts of Ethiopia is poor and that a significant number of households suffer from deficiencies in their daily calorie intake and problems relating to dietary diversity.

The result further indicates that the status of food security among irrigators and non-irrigators is found statistically different. However, this does not tell us whether this difference is as a result of irrigation practice because other confounding factors are not controlled for. Besides, claiming causality between irrigation use and food security cannot be made without rigorous impact analysis. Therefore, to address this fundamental question, the study employed the PSM model and discusses the result in the next section.

7.2.3 Propensity score matching (PSM) model results and discussions

Propensity score matching model was used to assess the impact of irrigation (KIDP) on household food security because it is assumed that participation in a program that promises food security cannot be randomly in practice; hence, the matching method is among the appropriate evaluation tools (Awulachew *et al.*, 2008; Nugusse & Speelman, 2012-2013). But this does not mean that PSM has no limitations. The basic limitations that confound impact evaluation in general and PSM, in particular, include selection bias, spillover effect and measurement error (Ravallion, 2005) where this study is not exceptional. The main concern is, therefore, to use the tips of matching the observable characteristics to reduce the level of bias.

The study used multidimensional household food security index and annual income as the outcome variables. Seven variables were identified to calculate the propensity score and for matching the irrigator with the non-irrigator households (Annex 8). The *Probit* regression model was used to estimate the propensity score based on which the matching step was subsequently done. The *probi*t model was also used to find how the selected variables influence the probability of irrigation participation.

As a result, the statistics suggest that the probability of participation in irrigation scheme more likely increases as household's private land holding size (PLANDSIZE), education level (EDUYRS) and family size (FAMSIZE) increases (Annex 8). The mean value of the estimated propensity score for all respondents is 0.56 (Annex10) which means the average probability of households to participate in the irrigation project was 56 percent.

The study checked the success of matching for each explanatory variable. A two-sample t-test was used to calculate the bias before and after matching for each independent variable and tested the hypothesis. The mean value for the majority of the independent variables between the treated and untreated respondents was higher and statistically different before matching, but it reduced and become statistically insignificant after matching process (annex 9 and annex 11). Thus, the study rejected the alternative hypothesis for many variables.

The average treatment effect (ATT) of irrigation was estimated using Nearest Neighbor, Radius, Kernel and Stratification matching estimators as robustness checks. These matching estimators were also used to check the consistency of the PSM results. However, the nearest neighbor matching method seems somewhat conservative since only 91 cases from a total of 175 non-irrigation user households were judged to be comparable to irrigators. In addition, the common support assumptions and balancing property of the data were checked and it was fulfilled and satisfied (Annex 10). The optimal number of blocks is six that implies the mean propensity score is not statistically different for the treated and untreated households in each block. After these checks, the remaining bias, if any, can be then attributed to unobserved characteristics (Awulachew *et al.*, 2008).

7.2.3.1 The impact of irrigation on households' multidimensional food security

Table 34 gives the estimates of average treatment effects (ATT) of irrigation on households' multidimensional food security based on Radius, Kernel, and stratification matching methods. Accordingly, the PSM result shows that the KIDP has a positive impact on household multidimensional food security but it was found to be statistically insignificant. The three matching methods consistently estimate that irrigation has no statistically significant effect on irrigator households' multidimensional food security status as compared to non-irrigators. This result is similar to the descriptive analysis that indicates an insignificant difference in multidimensional food security score among the two groups (i.e., without using PSM).

Table 34:Average treatment effects difference (ATT) of multidimensional household food security: Estimation results of matching methods

Impact on	**PSM Techniques**	**No, of Treated**	**No, of Control**	**ATT**	***t*-statistic**
Multidimensional household food security (MFI)	Radius	207	174	0.045(0.056)	0.797
	Kernel	220	174	0.022(0.059)	0.375
	Stratification	219	175	0.108(0.081)	0.336

Source: own calculation

Note: numbers in parenthesis are bootstrapped standard errors; 50 bootstrap replications are performed for kernel matching.

In order to validate this result, FGDs with irrigator and non-irrigator groups were conducted. The main focus was to assess farmers' perceptions on their food security experiences by assuming that perception could matter the level of their food security. From the discussion, we understood that the discussants perceived food security is “living with no hunger”. As per their definition, a household is considered as food secured when all family members in a household can be able to eat as much as filling their stomach in any time of need. Consequently, they ranked themselves “food secured”, but with the possibility of food insecure households in the community. On this issue, irrigation user FGD participants explained:

> *“Even if we might not be correct to the right meaning of food security, we assume that a household is food secured when a farmer could be able to feed his/her family members as much as filling their stomach in a time of food need. Hence, to our understanding, food security is living with no hunger. However, these days, experts have thought that food security is more detail than we perceive. As our understanding concerns, unlike the previous times, food problem is a serious issue in our community and we feel that we are food secure, though it does not mean that there is no food insecure household in our community. We also do not assume that we are more food secure than non-irrigator households because we thought that they do not face food shortfall and further our culture of diet is similar.”*

Non-irrigator FGD participants had this to say on the same point:

> *“Earlier times, we assume that food security is simply filling a stomach with any food item even it could be one type in every day. These days, extension workers have thought us and we understand that food security is beyond filling a stomach. As far as we know ourselves, we are food secure because we can eat food as much as we want at any time of need. Of course, there may be some households who have the problem of seasonal food shortage. We assume that irrigator households could earn more money from their farm than us because they produce surplus and sale to the market. However, they might not be more food secure than us since both we have no food problem.”*

From the FGDs results, we can infer that both irrigator and non-irrigator households understand the situation of food security similarly. Hence, their culture of diet is appeared to be similar. This implies that irrigation could enable users to enhance agricultural outcomes, but its effect might be less on knowledge of farmers to change this outcome into assuring food security.

Surprisingly, the finding of this study is different from the widely held view that irrigation has a positive and statistically significant impact on households' food security (Awulachew & Yilma, 2008; Gebregziabher & Namara, 2008; Nkhata, 2014; Owusu & Abdulai, 2009; Tesfaye *et al.*, 2008). The inconsistency with other studies perhaps is arising from measurement differences. Many of the above researchers have reached their conclusion based on using consumption expenditure and/or income proxies which failed to capture diverse dimensions of food security. To the contrary, multidimensional household food security index that is employed in this study is more comprehensive than consumption expenditure/income and addresses different food security dimensions.

7.2.3.2 The impact of irrigation on households' annual income

Many researches in the literature use income proxy to measure food security and their conclusions indicated the significant impact of irrigation on households' income which directly attributed to food security. However, this study employed the MPI and come up with a contrast result. Therefore, the study demands to expand the analysis and estimated the impact of irrigation on the households' annual income.

Table 35 gives the estimates of average treatment effects **(**ATT) of irrigation on households' annual income based on Radius, Kernel, and stratification matching methods. The percentage of annual income gain estimated by Radius matching method is higher than stratified and Kernel matching methods. Therefore, the estimate of Radius matching method was used to interpret the results. Accordingly, the result indicated that irrigation has a positive and statistically significant impact on the households' annual income. The bias-adjusted estimate shows that the average irrigation effect on annual income of the irrigating farmers was 35.2 %. This means the average annual income for irrigation users was 35.2% higher than that of non-irrigators. This also represented an average annual income increase of 35.2% more than what participants would have earned if they did not participate in the irrigation scheme.

Table 35:Average treatment effects difference (ATT) of irrigation on annual income: estimation results of PSM matching methods

Impact on	**PSM Techniques**	**No, of Treated**	**No, of Control**	**ATT**	***t*-statistic**
Annual income (LOGANNINC)	Radius	207	174	0.352 (0.08)	4.425**
	Kernel	220	174	0.249(0.085)	2.914**
	Stratification	219	175	0.204(0.080)	2.553**

Note: numbers in parenthesis are bootstrapped standard errors; ** significant at 5% level of significance; 50 bootstrap replications are performed for kernel matching.

Source: own calculation

The model result seems consistent with the output of the FGD made with irrigators. According to FGD participant farmers, they do recognize some benefits from the irrigation project. Among others, the project has created job opportunities for youths and opened chances to grow varieties of crops at least twice a year. These enable them to generate additional income than before.

In this connection, irrigation user FGD participants in the KIDP stated:

> *"First of all, we want to acknowledge the government for establishing the Koga irrigation development project for us which is enhancing our agricultural outcomes. The project is helping us to diversify crop farming and opened an enabling environment to produce crops twice a year. Then we make money by selling some of the products. It has also created different job opportunities for our young children such as day laboring which, in turn, strengthen our household's source of income. Therefore, we have a full mouth to say that the project has enhanced our income than ever before."*

The finding regarding irrigation impact on annual income has compared favorably with findings from other studies and is generally consistent. For example, studies undertaken by Christine *et al.* (2008) and Tesfaye *et al.* (2008) confirmed that the annual income of beneficiary households increases as there is access to reliable irrigation water. For example, in Ghana, irrigated income has increased by about 30-50% of the household incomes (Kuwornu & Owusu, 2012). Asiribo (2009) in Nigeria reported similar findings that indicate as small-scale irrigation is a source of income and employment. Consistently, Nugusse &Speelman (2012-2013) found that irrigation is one of the sources of household income and farm households earn higher average annual income than rain-fed farmers.

7.2.3.3 Discussion on the results of impact of irrigation on income vs food security

There is a widely held view that increased income is accompanied by improvements in food security. Most researchers argue that irrigation has statistically significant impact on food security when irrigators could earn more income than their counterparts, and the households are considered better of food secure. However, the finding of this study is different from this argument. It reveals that irrigation has increased the annual income of irrigating households but it had no statistically significant impact on households' multidimensional food security. Therefore, this case apparently indicated that access to irrigation could increase an annual income per household, but it does not necessarily mean that the household is better food secured. Because, if the increment of annual income is highly attributed to food security, this study should find better food secured irrigators than non-irrigators since irrigator's average annual income was higher than the non-irrigators. This result can be explained by the following reasons: 1) since the multidimensional food security measurement considers beyond income dimensions of food security, both irrigators and non-irrigators would score closely similar cumulative experience. (2) As compared with the non-irrigator households, the irrigators might not have special awareness about food security and nutritional food, which results in using their income for non-food items. Practically, whatever farmers have money in their pocket, unless they got empty or face critical shortage of food in their store, their habit of purchasing food items for variety and nutritional purpose is very poor. Actually, this was confirmed by FGD participants in both groups. As per the explanations, farmers have allocated their generated income for non-food items such as agricultural inputs, children education, purchasing durable assets and other luxury commodities. In some extent, non-irrigators have accustomed purchasing some food items such as fruit and vegetable for their children in dry season. Generally, it was indicated that the feeding habit of both irrigators and non-irrigators was strongly confined to few food items, however, the culture of including fruit and vegetable to their usual dish is improving, but not meat and egg diets. Regarding to their income allocation, participants in both FGDs stated:

> *"It is clear that money allocation varies from farmer to farmer. Nonetheless, we allocate our income for non-food items such as purchasing agricultural inputs, educating our children, covering health expenses, buying durable assets (such as livestock, cart, Bajaj, mobile, bicycle, etc.) and maintaining or rebuilding our houses and etc. Except for some industrial products such as oil, salt, sugar and etc., our culture of using the money for buying food items in view of food security is poor because most of the products in the market are what we produce in our field. If our stock is not totally empty, we prefer to consume what we have in home even it could be one type."*

(3) The irrigators might encounter unexpected problems such as shortage of water, natural disasters, and risk in production or crop failure. In line of this, the informal discussions with farmers and the key informant interview with the *Koga* project office indicated that the irrigated agriculture before and during this survey has faced a shortage of water due to *El Niño* effect which was occurred in Ethiopia from late 2015 to early 2017.

7.3 Impact of Irrigation on Households' Multidimensional Poverty Reduction[8]

7.3.1 Descriptive summary

Summary statistics and statistical significance tests on the socio-economic profile of adopters and non-adopters for continuous and binary variables indicated that except gender of the household head and land covered by crop, there was a significant difference on other variables. The two groups were statistically different in their average MPI. The non-irrigators had higher MPI than their counterparts. This implies non-irrigators were poorer than irrigators. Significant differences were also noticed for variables such as average farming income, ownership of total land size, farm ox, access to information (own radio/mobile/TV), and agricultural input supply with higher mean levels for all of these variables in favor of irrigation participants. This suggests that these variables might be correlated with the decision to irrigation adoption. However, the assumption of farmers about the marketability, high yield expectancy and climate change resistance capacity of crops they grow was higher in favor for non-irrigators (see the details of other variables in section 4.5.1).

[8] "**Impact of Irrigation on Households' Multidimensional Poverty Reduction**" is a published article on *Journal of Poverty Alleviation & International Development,* Asian Development Perspective.

Table 36: Descriptive summary of selected variables used in estimations.

Variable	Non-Irrigators (N=175)	Irrigators (N=220)	t-test/ x^2 value
Outcome variable			
Multidimensional poverty index (MPI)	0.33	0.21	7.4***
Household characteristics variables			
Age of household head (years)	40.5	42.7	-1.8**
Gender of household head (1=male)	0.30	0.38	0.78
Marital status of household head (2=married)	0.43	0.51	-7.2***
Family size(number)	5.18	6	-4.1***
Length of residence at the area(years)	35.8	38.5	-1.9*
Education level of household head (years)	9.3	8.4	3.5***
Member of Edir[9] (1=yes)	0.41	0.47	4.6**
Household wealth variables and farm characteristics			
Household head farming experience (years)	20.7	22.9	-1.7*
Household farm income (Birr)	6,337.7	11,442.3	-5.8***
Total land size(ha)	2.2	2.8	-5.5***
Land covered by crop(ha)	0.88	0.89	-0.3
Own farm ox	1.4	1.7	-2.8***
Crop marketability(1=yes)	0.35	0.37	11.2***
Growing crop type by expecting high yield(1=yes)	0.41	0.54	6.9***
Crop resistance of climate change(1=yes)	0.37	0.32	24.2***
Institutional and access related variables			
Input supply(1=yes)	0.29	0.32	4.0**
Access to media (1=own radio/tv/mobile)	0.28	0.42	6.7***

Note: ***, ** & * are significance levels at 1%, 5% & 10%; Standard errors in parentheses

Source: own household survey

[9] *Edir* is a traditional social/mutual aid association practiced in Ethiopia.

7.3.2 Household multidimensional poverty analysis in the study area

7.3.2.1 Households deprivation in indicators

Prior to identifying multidimensional poor households, the AF methodology determines whether a household is deprived in a particular indicator (i.e., the first cut-off), as indicated in Table 37. It is used to know the minimum achievement level required from a household to be considered as non-deprived in that indicator (Alkire & Foster, 2009).

Table 37:Crude deprivation rates of households by indicators (%)

Dimension	Indicator	Deprived households
Education	Years of Schooling	25.3
	Child school attendance	23.8
Health	Child Mortality	1.5
	Access of health facility	26.6
Living standard	Electricity	29.9
	Improved Sanitation	24.8
	Safe Drinking Water	27.1
	Roofing	2.0
Productive assets	Livestock index	32.7
	Durable asset	61.3

Source: own household survey

The rank order of indicators displayed that the first, the second and the third highest deprivation rates are found in the 'productive asset' and 'living standard' dimensions: durable asset (61.3%), livestock (32.7%) and electricity ownerships (29.9%), respectively. The figures indicated the percentage of deprived households that were unable to meet the minimum achievement set to the respective indicators. For example, about 61% of the sample households deprived in durable assets such as car, Bajaj, motorbike, bicycle, cassette player, radio, mobile, hand insecticide pump or water pump. It is also explained that 32.7% of surveyed sample households did not have more than one item or two quantities in an item of the following livestock asset groups: beef cattle, milk cow, breeding bull, farm ox, goat, sheep and equine (donkey/horse/mule). Though 26.6% of sample households were lived without access to the health facility or accessed after an hour trip from home, the proportion of deprived households in child mortality was smaller (1.5%). About 23.8%

of households have school-aged children who were not attending their school. As compared to the finding of Ambel *et al.* (2015), the result shows that there is an improvement in child school engagement because he found that the proportion of households with school-aged child who were out of school was 58 percent in rural areas. The improvement in this regard is more dramatic in some areas of Ethiopia. For example, the finding of WIDE reported that nearly all 7 years old children were enrolled in school in the six study sites visited in Ethiopia in 2013 (Bevan *et al.*, 2014). Even though school engagement was improved, about 25.3% of sample households had no family member who has completed 8 years of schooling. About 27% of households were leading their lives without access to safe drinking water or can access after 30-minutes round trip from their home and 24.8% live without improved sanitation facility. This indicates that the proportion of households deprivation in improved sanitation and safe drinking water of the study area is smaller than the average deprivation in Ethiopia, which were 45% and 59% in 2011, respectively (Ambel *et al.*, 2015). Among the living standard indicators, only 2% of sample households were deprived in roofing. This illustrates that households at the study area could be able to have improved type of homes. Overall, the single deprivation analysis shows that as compared to previous studies there are deprivation improvements and there is deprivation difference among dimensions at the study area.

7.3.2.2 Multidimensional poverty profile of households

The second cut-off in the AF methodology identifies the deprivation status of households in weighted indicators. Accordingly, 69.4% of the sample households (non-poor, non-deprived and vulnerable to poverty) were found to be multidimensional non-poor. Out of them, 10% were not totally deprived in any of the indicators, whereas 59.4% were deprived in at least one indicator. Amongst the deprived non-poor households, about 31.7% are deprived by 0.1-19.99% of the weighted indicators and are classified non-poor, but 27.6% were deprived in range from 20% up to 33.3% of weighted indicators and hence they are suspected to be ‘vulnerable to poverty’ (Alkire & Foster, 2009; Ambel *et al.*, 2015). On the other hand, about 7% of the sample households were deprived in more than 50% of weighted indicators. According to the classification of Alkire *et al.* (2015) and Hailu *et al.* (2018), these households are multidimensional poor within a severe poverty situation (Table 38).

Table 38: Households' poverty profile

Category	**No, of households (%)**
Non-poor households (MPI =0.1-19.99%)	31.65
Non-deprived households (MPI=0)	10.13
Vulnerable to poverty (MPI =20-33.3%)	27.59
In severe poverty (MPI>=50%)	7.34

Source: own household survey

As can be vividly indicated in Table 39 below, about 30.6% of surveyed households were found to be multidimensional poor which implies that they were deprived by at least 33.33% of the weighted indicators. This result indicates the unadjusted head-count ratio (*H*) of poor households at the study area. This actually gets smaller as compared to the national percentage of MPI poor people estimated in 2016 which was 87% (OPHI, 2016). The poverty intensity rate (A) of the study area was 47%. This indicates that the poor households were deprived by 47% of the average weighted indicators or by 1.88 dimensions. The adjusted headcount ratio *(Mo)* shows that multidimensional poverty index in the study area was estimated to be 14.4% and each MPI poor household has experienced simultaneous multiple deprivations. The contribution of productive asset dimension to *(Mo)*, followed by education dimension, was quite high which is 39.5% and 24%, respectively. On the indicator level, durable asset had the highest contribution (23.5%) to *(Mo)* whereas the contribution of roofing was very low (0.4%), explaining that nearly all households at the study area were not living in grass thatched homes (annex 14).

Table 39:Multidimensional poverty profile

Category	**No, of households (%)**
poor households *(H)*	30.6(0.02)
Poverty intensity *(A)*	47.1(0.01)
Multidimensional poor households *(MO)* =(H*A)	14.4(0.01)

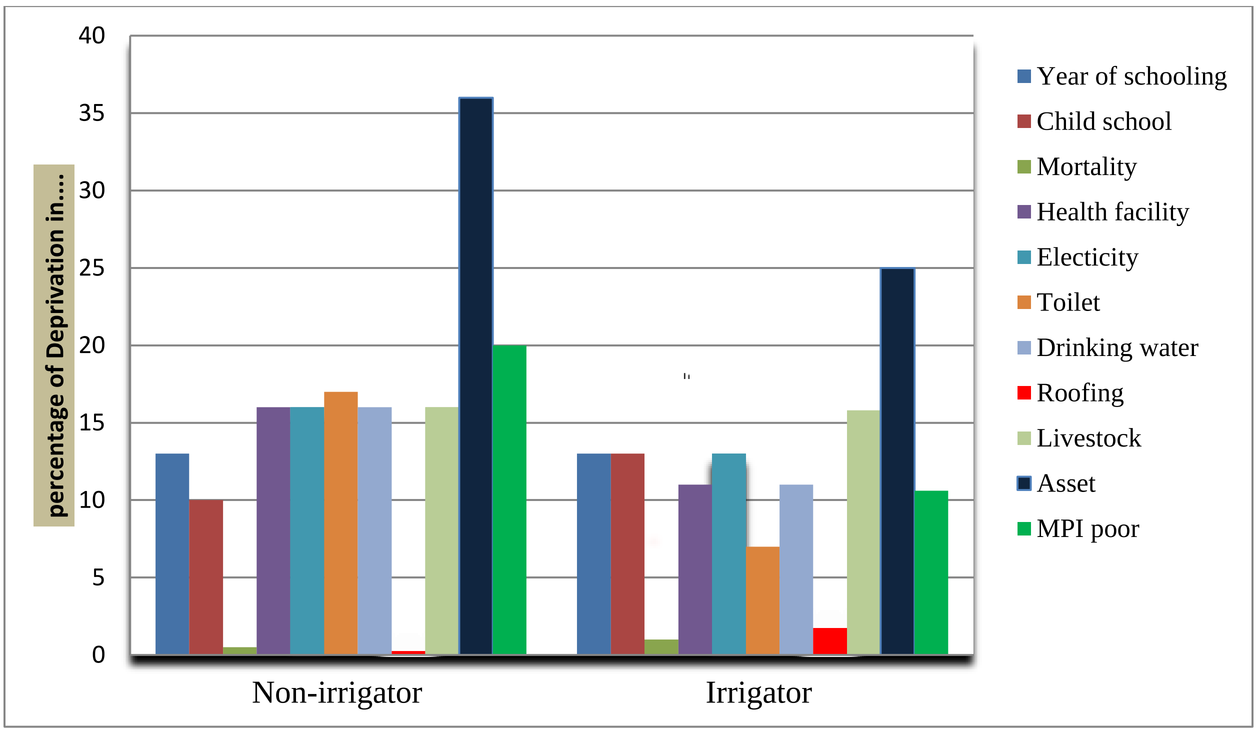
Source: own household survey Note: values in parentheses are standard errors.

The result of the study is consistent with the finding of Ambel *et al.* (2015) who confirms that there have been significant reductions of deprivations in many dimensions, particularly in rural areas. Similarly, our finding reveals that the MPI of the study area is highly lower than both the national average and regional average which is 56.2% and 58.8%, respectively (OPHI, 2017). The area has also much smaller MPI than the estimated national rural MPI (63.7%) (OPHI, 2017).

7.3.2.3 Decomposition of Multidimensional Poverty by Irrigation use

Another useful trait of the MPI measure is that it can be applied to population subgroups and it is used to compare the progress of different groups and potentially identify those at risk of falling behind (Alkire *et al.*, 2017). Accordingly, the study examines the distribution of poor people across irrigation households and non-irrigation households. It also evaluates whether the progress of poverty reduction was evenly achieved across the two groups. Figure 8 presented below indicated that non-irrigator households were deprived by majorities of indicators. The MPI is also higher in non-irrigator households.

Figure 8:Level of deprivations and proportion of MPI poor households across irrigation use



Source: own survey data

As clearly shown in Table 40, the incidence of poverty in non-irrigating households (44.6%) was higher than irrigating households (19.5%). Not surprisingly, there was much variation in the proportion of multidimensional poor by irrigator and non-irrigator households. From the total MPI poor households, 21% were non-irrigation users and the remaining 9% were irrigator households. When we decompose MPI by kebele groups, there was a considerable variation among different community groups. Enashenifalen kebele, had a greater proportion (64.6%) of multidimensional poor households, whereas Enguti kebele had the least proportion of MPI poor with a share of 4.3%. The later kebele uses irrigation, but the former does not use and this also confirms MPI difference among irrigation users and non-users.

Table 40: MPI decomposition by sub-groups

Sub-groups	**Categories**	**Pop. Share**	**H**	**Mo**
	Non-irrigator	0.443	0.446	0.210
Irrigation user	Irrigator	0.557	0.195	0.092
	Kudmi	13.9	32.7	14.5
	Enguti	10.6	9.5	4.5
Kebeles	Amarit	19.5	24.7	12.3
	Tagel wodefit	11.6	4.3	1.8
	Kurit Bahir	10.1	47.5	24.5
	Enashenifalen	16.5	64.6	30.3
	Abiyotfana	17.7	24.3	10.4
Total		100	30.6	14.4

Source: own household survey

This result of the study highlights that poverty reduction is not equally progressed in irrigating and non-irrigating households and it varies in local administrative areas as well. Both the proportion of poor households and MPI were higher in non-irrigating households. Inline of this, the interview with KIDP office indicate that up on the operation of the project, the living standard and income of irrigation beneficiaries become improved. They also believed that poverty in their context is low in irrigating households than rainfed farm households. This is consistent with the finding of Namara *et al.* (2008) who argued that the depth of poverty for irrigators is less than those without access to irrigation. The result also suites to the idea of (De Neubourg *et al.*, 2010; Dhongde & Haveman, 2015) which argued that poverty rates vary by geographic or administrative regions, the degree of urbanization and technology adopting groups. Overall, it should be noted that the incidence of poverty among the sample households is still higher irrespective of access to irrigation.

Even though the above discussion revealed that rainfed farm households were poorer than irrigator households, the key research question remaining is, whether irrigation adopters are better off than non-adopters as a result of the impact of irrigation. This fundamental question is therefore addressed by applying the switching regression model in the following section.

7.3.3 The endogenous switching regression model results and discussion

The Differences in poverty outcome may not be due to irrigation adoption itself but unobserved ability and characteristics that could affect households' relative welfare. Hence, to check whether the arguments are correct, the full maximum likelihood estimation of endogenous switching model that can control for unobservable selection bias is presented in Table 41 (see the detail STATA output from annex 15). The estimation consists of both irrigation participation/adoption model and outcome model for irrigators and non-irrigators. The determinant forces behind farmers' decisions to participate in irrigation use and poverty status of households are also presented where the dependent variable is dummy and the outcome variable is continuous.

Among model estimating variables, access to media/information (own radio/TV/mobile) used in the adoption equation is excluded from outcomes equation, to meet the condition of model identification (Asfaw *et al.*, 2012; Kuwornu & Owusu, 2012; Nonvide, 2018). The hypothesis behind was that this variable affects the probability of irrigation adoption. It is believed that a household that owns radio/mobile/TV have access to information. Accessibility to information is key to be aware of the contribution of adopting irrigation to reduce household poverty. Since irrigation adoption is an investment where farmers spend extra capital, they might not adopt it unless they have a clear idea about its profitability. However, access to information without adopting irrigation does not directly affect the multidimensional poverty.

Estimates of the endogenous switching model revealed that the model has a high fit with its explanatory variables. The Wald test of independence confirming the sample selection bias and was significant at 1%. This implies that at least one of the explanatory variables significantly explains the variation in household poverty. The correlation coefficient (Rho_1) between the equations of irrigation adoption and MPI was positive and significantly different from zero (at 1% significance level). According to Lokshin &Sajaia (2004), this suggests that the mean MPI of those who irrigate is higher than randomly selected households mean for irrigators, and those not using irrigation do no better or worse condition than a random individual for non-irrigators. This further implies that the irrigation adoption decision and MPI outcome are affected by observable and unobservable factors (Xie, 2000).

Table 41: Full information maximum likelihood estimates of the switching regression model

Variables	Irrigation adoption model	Outcome model	
		Irrigating farmers	Non-irrigating farmers
Age of household head	0.04(0.01) ***	0.01(0.00) ***	0.00(0.00)
Marital status household head	-0.84(0.33) **	-0.08(0.05) *	-0.05(.08)
Length of residence at the area	-0.02(0.01) **	-0.002(0.00) *	-1.59e-06(0.00)
Education level	-0.07(0.03) **	0.00(0.00)	-0.01(0.01)
Member of edir	-0.32(0.23) **	-0.08(0.03) **	-0.09(0.04) **
Household head farming experience	-0.01(0.01)	-0.004(0.00) **	-0.002(0.002)
Log household farm income in birr	0.43(0.08) ***	0.02(0.02)	-0.01(0.01)
Total land size per ha	0.38(0.11) ***	0.04(0.02) **	-0.04(0.02) *
Land covered by crop per ha	-1.39(0.25) ***	-0.16(0.04) ***	0.07(0.06)
Own farm ox	0.02(0.08)	-0.05(0.02) ***	-0.05(0.02) ***
Crop marketability	-0.43(0.19) **	-0.04(0.03)	0.05(0.04)
Expecting high yield	0.87(0.44) **	0.09(0.07)	0.21(0.06) ***
Crop resistance of climate change	-0.57(0.16) ***	-0.06(0.03) **	-0.09(0.04) ***
Input supply	0.12(0.16)	-0.03(0.03)	.01(0.03)
Access to media (radio/TV/mob.)	0.36(0.12) ***	-	-
-cons	-2.60(0.82) ***	0.09(0.16)	0.53(0.09) ***
/lns1	-1.70(0.06) ***	-	-
/lns2	-1.95(0.08) ***	-	-
/r1	2.09(0.39) ***	-	-
/r2	0.39(0.30)	-	-
sigma_1	0.18(0.01)	-	-
sigma_2	0.14(0 .01)	-	-
rho_1	0.97(0.02) ***	-	-
rho_2	0.38(0.26)	-	-
N	395	220	175

Log likelihood = 44.32; Wald chi2(14) = 69.57; Prob > chi^2 = 0.0000
Wald test of indep. eqns.: chi2(1) = 31.43; Prob > chi2 = 0.0000

Note: ***, ** & * are significance levels at 1%, 5% & 10%; Standard errors in parentheses
Source: own household survey

7.3.3.1 Determinants of irrigation adoption and multidimensional poverty

The results of the adoption model given in the second column of Table 41 revealed that the coefficients of most of the variables hypothesized to influence participation in irrigation use have the expected signs. Variables such as age, marital status, length of residence, level of education, *edir*, farming income, total land size holding, land covered by crop, crop marketability, crop resistance to climate change, high yield expectancy from a growing crop and access to media are statistically significant in explaining the decision to participate in irrigation use. Of these determinant factors, the age of a household head, income from farming, total land size owned by household and high yield expectancy are positively influenced households to be a member of the project.

It is indicated that a unit addition to age most likely improves the probability of participation. This attributes to the fact that older farmers might possess richer farming experience that could be easily harnessed for improved irrigation activity (Kuwornu & Owusu, 2012). A unit increase of income from farming agriculture and land size positively influences the probability of household participation in the irrigation project. One possible explanation is that these assets ease the access of households to agricultural inputs and afford the costs so that they could adopt the technology. Those farmers who expect high yield from a selected type of growing crop are also more likely influenced to adopt irrigation. Consistent with the hypothesis of the study and the findings of Asfaw *et al.* (2012), the result shows that irrigation adoption is most likely determined by the proxies of access to information such as radio, TV, and mobile. This implies that ownership of these assets eases the access of households to information. Hence, households who have access to information about irrigation are likely urged to adopt it. In connection to this, the coefficients for variables such as marital status, length of residence, education level, membership of *edir*, cropped land size, crop marketability and perception of households on crops resistance to climate change are a negative sign, but are statistically significant determinants of irrigation adoption.

The determinants of household's multidimensional poverty status in irrigated and non-irrigated households are also presented in Table 41. Variables such as total land size, membership of *edir*, farm ox ownership and perception of households on crop's resistance to climate change significantly contribute to multidimensional poverty reduction in both irrigated and non-irrigated households. Holding the large land size and number of farm oxen are wealth proxies in the study area. Hence, it is not surprising that a unit increase of these assets plays a significant role in household's effort to reduce poverty. Expectedly, the contribution of *edir* for poverty reduction in both groups is statistically significant because it is a traditional social/mutual aid association practiced in Ethiopia. Perception of households on crops resistance to climate change also negatively influences poverty (i.e., reduce poverty) in both groups. The explanation behind this result indicates that farmers are experienced and skilled in identifying and growing climate resilient types of crops. Selectively growing a type of crop by expecting more yield than other crops was the additional variable that significantly determines poverty in non-irrigator households. In other words, those farmers who perceived the type of crop they choose to grow provides high yield most likely lowers their MPI. In the irrigator households, the age of household head, marital status, length of residence at the area, farming experience and size of land covered by crop significantly decreases multidimensional poverty. One possible explanation is that aged and long resident as well as experienced farmers might know the local opportunities to reduce poverty such as agro-ecology, nature of the soil, type of crops suitable to the environment and feasible income generating activities.

7.3.3.2 Predicted impact of irrigation on households' multidimensional poverty reduction

The predicted MPI from endogenous switching regression model is used to examine the mean MPI gap between irrigators and if they had not irrigated. Table 42 presents the expected MPI under actual and counterfactual conditions for irrigator and non-irrigator households at the study area. Cases (a) and (b) are the expected MPI values observed in the sample which were 0.21 for the irrigators and 0.33 for the non-irrigator households. A t-test analysis (t =-15.04 significant at 1%) between the two groups indicated that irrigation households had significantly lower MPI with the difference being 11.5%. This illustrates that the expected multidimensional poverty of irrigators is lower than non-irrigators. However, it cannot be attributed to the use of irrigation alone (Asfaw *et al.*, 2012; Nonvide, 2018). Therefore, based on this simple comparison, it can be misleading to attribute the different level of observed poverty to the use of irrigation.

Table 42: Average expected MPI for irrigating and non-irrigating households

Sample groups	Decision stage		Treatment effects
	Irrigate	**Not irrigate**	
Irrigators	(a) 0.219(0.005)	(c) 0.394(0.006)	**TT**=-0.175(.007) ***
Non-irrigators	(d) -0.042(0.006)	(b) 0.333(.006)	**TU**= -0.375(.008) ***
Heterogeneity effects	$\mathbf{BH_1}$=0.26(.008) ***	$\mathbf{BH_2}$=0.06(0.008) ***	**TH**=0.2(0.008) ***

Note: *** is significance level at 1%; Standard errors in parentheses
Source: own household survey

As a result, the treatment effects report of irrigation adoption was used. Note that the negative/positive signs of TT and TU indicate the direction of poverty. For example, if irrigators are less poor than non-irrigators, the MPI mean value for irrigators should be smaller than their counter group and hence when we subtract the result is negative and vice-versa. It is estimated that in the counterfactual case (c), the irrigator households MPI would have been 0.175 more if they did not adopt irrigation. This implies that if the irrigator households did not irrigate, they would be 17.5% more poorer than what are today. The effect of irrigation on non-irrigator households in the counterfactual case (d) show that if the non-irrigator households had adopted irrigation, their MPI would be lowered by 0.375. The result reveals that if the non-irrigators adopted irrigation, they would reduce poverty by 37.5%. The TH value in the table shows that the transitional heterogeneity effect was positive and significant (0.2) implying that the effect of using irrigation was significantly bigger for the non-irrigator households if they irrigate. If they did adopt irrigation, the non-irrigator households would be 20% less poor than irrigators. The heterogeneity effects reveal that the non-irrigator households would have been poorer than the irrigators in the counterfactual case (c), and case (d).

The findings of this study suggest that there is a positive relationship between irrigation adoption and household's multidimensional poverty reduction. Irrigating farm households reduce their multidimensional poverty by 17.5%. This illustrates that the contribution of irrigation to reduce household multidimensional poverty at the study area was 17.5%. The result is consistent with previous findings of Nkhata (2014), Ayele *et al.* (2013) and Hussain &Wijerathna (2004) who reported that there are indicative patterns of farm households' poverty in large and medium-scale irrigation systems. Irrigation development has a profound direct impact on agriculture output levels. It boosts total farm output and hence, with unchanged prices, raises farm incomes thereby reduces poverty (Lipton *et al.*, 2003). In 2002-2003, IWMI carried out detailed case studies on assessing impacts of irrigation on poverty alleviation in Bangladesh, China, India, Indonesia, Pakistan, and Vietnam. The finding indicated that in most settings, poverty incidence is 20-30 percent higher in rain-fed settings than in irrigated settings (Hussain & Wijerathna, 2004). Irrigation also significantly contributes to reducing the worst kind of poverty, i.e., chronic poverty. The poverty incidence, depth and severity were also found to be lower among irrigation households than among non-irrigation household (Meliko & Oni, 2011).

However, the impacts of irrigation on poverty vary widely across and within irrigation systems and depend on a number of factors(Hussain & Wijerathna, 2004). Therefore, incidence, depth and severity of poverty are affected more by the intensity of irrigation use than mere access to irrigation (Namara *et al.*, 2008). For example, Fitsum *et al.* (2009) found that due to improved efficiency and management, the bulk of the contribution to the national economy comes from the smallholder managed irrigation schemes; most importantly from the traditional schemes.

Therefore, it is suggested that simple access to irrigation is not a sufficient condition to alleviate poverty in rural households who are dependent to a great extent on agriculture for their livelihoods. Besides, access to other production inputs and services, low cost of irrigation uses and awareness on efficient utilization of the system are important to enhance benefits of irrigation for poverty alleviation.

7.3.4 Does households' multidimensional poverty vary in irrigation intensity?

The above sections show that there is a statistical multidimensional poverty level difference among irrigator and non-irrigator households and it was confirmed that irrigation has a positive and significant impact on poverty reduction. While the determinants of household poverty are numerous and complex, it is to a large extent associated with the level of irrigation intensity when there is low, inequitable, and unreliable water supplies within the system. Here, we present the MPI analysis across reaches within the irrigation system (upper, middle and lower catchments) based on the descriptive finding that irrigation intensity varies in each reach. This is important to see whether the impact of irrigation on poverty differs among irrigation users.

Table 43:households multidimensional poverty level by irrigation intensity

MPI category	**Irrigation category (location from dam)**			**Total**
	Upper catchment	Middle catchment	Lower catchment	
H	0.315	0.068	0.256	0.195
Mo	0.138	0.031	0.129	0.092
Pop. share	0.245	0.400	0.355	1.000

Source: own field survey data

The result given in Table 43 indicates that the incidence of poverty and MPI poor are different across irrigation reaches. The headcount poor people and MPI poor are greater in the upper catchment than the middle and lower reaches. On the other hand, the incidence of poverty and MPI poor are lower in the middle catchment as compared to the upper and lower catchments. Literally, this result accounts for potential differences in the availability and access to water across reaches in the KIDP. This also further associates to the households' poverty level. Based on this statistic, we can understand that the middle reach has better access to irrigation water and poverty is lowered than the two. The result suites with the study of Hussain (2007) who found that poverty is significantly lower at middle reaches than that of head and tail reaches; poverty is high where availability and access to surface water are low, groundwater quality is poor, agricultural productivity is low and opportunities in the nonfarm sector are limited. According to Hussain (2004), let alone large schemes, within small schemes, some farmers might have an adequate supply of water while others have insufficient water and may even be forced to abandon their crops.

7.3.5 Opinions and perceptions of key informants on the contribution of KIDP for poverty reduction

Basically, the study has employed the key informant interviews to triangulate the findings of the econometric statistics and increase the validity of results. The main focus of the interview was to ascertain the extent to which the project has affected households' poverty status. Their personal opinions about the benefits of the project, their satisfaction level, poverty trend and the measures to be taken for better performance of the project were assessed. The KIDP project office and farmers (relocated and host) were the identified key informants. To illustrate the details of the presentation and discussion, the following three cases have been chosen.

Case 1: Girmachew Amare

"I am one of the former dwellers at this kebele in the command area. At the construction phase of the project, we have heard that the project was established with big irrigation capacity. As a result, we have had big hope on the full adequacy of the service; unfortunately, due to many reasons, it is not satisfactorily adequate. However, with all the limitations, I am happy on the commencement of the project because it enables me to share the tips. Even if I am not rich in landholding, the irrigation service enables me to use my plot effectively. I am harvesting crops twice a year; especially market-oriented cash crops such as head cabbage, potato, onion and garlic which are good sources of household income. In addition, I and my son make money from some off-farm activities to supplement our farm income. As a result, my income has improved and now I feel that I am in a better standard of living. When I compare my current poverty level and the poverty status before using the project, I can say that it is totally different on fever of my current life. Currently, I can easily afford the costs of children school, health and agricultural inputs. I thought that irrigation beneficiaries will be better off if the scheme has adopted good governance and use advanced water delivering technologies."

Case 2: Simegnew Takele

"I am a newcomer to Amarit Kebele dislocated from Sebehatie Kebele before six years. In the name of the dam and canal construction, I lost my land and eucalyptus trees and then forced to resettle at this Kebele without appropriate compensation. Even so, I was happy to be a beneficiary of irrigation. It is good to see such technologies though it is not well

managed. For example, due to the tertiary canal problem, blocks do not equally share water which minimizes our satisfaction. Another big challenge for irrigation users is input costs. However, the benefits outweigh the challenges. The project enables me to produce fruit, vegetables and staple crops two times in a year. My production increases from time to time. In addition, my children have engaged in alternative jobs to support themselves. As a result, I sense it as I am in a good life. I found it difficult to compare my poverty level before and after I use irrigation. I thought this one is by far better than before. Of course, I am still poor, but better poor. For instance, solar light, mobile and bed with Kangaroo foam are the assets that I could purchase by selling garlic and cabbage which I grow them using irrigation. I feel that I and my neighbors will enjoy more improved life if the water and input supply problems are addressed."

Case 3: Tewachew Abebe

So as to understand the improvement level of farming communities in the command area, *Ato Tewachew*, director of KIDP was interviewed. His demonstration about the life situation of irrigation beneficiaries was consistent with what farmers explained. He stated:

"Needless to say, the project has been playing an incommensurable role in household poverty reduction. It enables farmers to utilize their land effectively. They could harvest highly marketable farm crops twice a year, rather than only once as they did before. In our production assessment reports, we found that the trend of production improvement is continuous. Besides, farmers could be able to engage in alternative job opportunities to support their farm income. The community in the command area could also easily access road and transportation which they could not access if the project had not been commenced. Even though we did not study the exact poverty status of households, we observe that their living standard is improving. However, I want to note you that the system is providing the service within various ups and downs such as administrative ownership problem, water shortage and conflict of interest. In my opinion, the project will sustainably serve beneficiaries if it is administered by the community and adopt new irrigation technologies."

In a general view, the key informants were not fully satisfied by the provided service as much as they kept from the project. They thought as the project would make them more profitable than what it does today. However, they recognized that the project has played a significant role in enhancing their livelihoods and reducing poverty. They assured that their living standard has improved upon they started to be irrigation beneficiaries. They also could access infrastructural opportunities such as road and transportation, and they felt proud as if they would never be the divisible part of such development blessings if the project was not commenced. The result of the interview is matched with the finding of Gebre *et al.* (2008) who argue that irrigation beneficiaries would increase their production capacity, access infrastructural opportunities and improve their living standards. Analogously, (Fitsum *et al.* (2009)) have found that irrigation farming generates more average income than rainfed farming. Furthermore, the result suites to the econometric model results of the study and hence it assured that the finding is valid.

7.4 Chapter Summary

It is found that even though *Mecha woreda* is one of the agriculturally potential areas in Amhara region, only 12.4 percent of sample households were multidimensional food secure, whereas 14.4 percent of households were under a serious food insecurity situation. However, majorities of the sample households were mildly food insecure. It was estimated that irrigation has positive and statistically significant impact on household's annual income. However, its impact on multidimensional household food security was found statistically insignificant. The FGD result also confirms the effect of irrigation was apparently high on income, but not on the knowledge of food security and feeding habit of irrigators, which in turn, associates to the level of household's food security.

The rank order of indicators displayed that the first, the second and the third highest deprivation rates are found in the 'productive asset' and 'living standard' dimensions, respectively. About 69.4% of the sample households were found to be multidimensional non-poor and 27.6% were vulnerable to poverty whereas 7% of the sample households were severely poor. Among poor households, 30.6% of surveyed households were multidimensional poor. The poverty intensity rate of the study area was 47%. The adjusted headcount ratio shows that multidimensional poverty index in the study area was estimated to be 14.4% and each MPI poor household has experienced simultaneous multiple deprivations.

Finally, the study found that the impact of irrigation on households' multidimensional poverty reduction at the study was 17.5%. The outputs of the endogenous switching regression model, MPI analysis and the key informant interview consistently indicated that irrigators were less poor than their counterparts. It was also found that the impact of irrigation varies as irrigation intensity varies across irrigation reaches.

CHAPTER EIGHT

CONCLUSIONS, POLICY IMPLICATIONS AND AREAS FOR FUTURE RESEARCH

In this chapter, the conclusions, policy implications and areas for future research are presented. First of all, the conclusions which are formulated based on the results and findings of the study are drawn. Then, the recommendations that are established based on the formulated conclusions are presented. Both conclusions and policy implications are formulated and presented for each objective in a separate paragraph. Having argued on these parts, finally, this section presents the future research areas which are identified under this study and believed that they are potentially investigable, but are delimited in this research.

8.1 Conclusions

The main objective of the study is to assess water sharing mechanisms, crop choice decision factors and the impact of irrigation on food security and poverty reduction. For this purpose, the *Koga* irrigation development project in Northern Ethiopia was selected.

Assessing water sharing mechanisms and farmers' participation in collective irrigation management activities and identify the determinant factors that affect farmer participation is important for formulating sustainable large scheme irrigation management policies. Given the high rate of low performance of irrigation schemes after the withdrawal of government ownership, proper water sharing mechanisms and beneficiaries' active participation in collective actions remain vital. The study, therefore, assessed water sharing mechanisms applied in the KIDP and households' participation in collective scheme management activities by employing Ostrom's collective action theory and PCA econometric model. The study has also assessed the linkage between the water sharing methods with farmers' crop choice decision in the system. Inline of this, the factors that affect farmers' crop choice decision in the *Koga* irrigation development project were identified. The multinomial logit (MNL) model was used to investigate the factors guiding the households' crop choice decision. In the model, the dependent variable includes different crop choice categories and the explanatory variables include different household, institutional, and social factors. Having argued on the method of field water application and types of crops cultivated in the scheme, the study has evaluated the contribution of KIDP on household's food security and poverty reduction. It is assumed that water sharing mechanism and the types of crops cultivated in the scheme are largely associated with household's food security and poverty status. Food security was measured through household multidimensional food security index (MFI) and household poverty level was measured through multidimensional poverty index (MPI). The impact of irrigation was estimated by using PSM and endogenous switching regression models.

The study concluded that the water sharing mechanism used in the investigated case study was traditional and poor as compared to the standards for modern irrigation schemes water application system used in agriculture. Regardless of water demand of the growing crop, nature of soil, irrigation period and other critical factors, water has been shared in a similar schedule set for all types of crops which is less appropriate to decide when and how to apply field water equally across the irrigation reaches.

The finding shows that the sustainability and performance of large-scale irrigation schemes depend on the beneficiaries' commitment to use the system governed by the abide rules and agreed norms. The irrigation users in the KIDP give a priority to participate in regulation and control activities than decision making and labor based collective management activities. An interplay of socio-economic and institutional-based attributes greatly influence users' participation in collective management of schemes. In view of the fact that better annual income from irrigation agriculture, water-related meetings and pieces of training, being a member of the WUA and access to credit and extension services are positively associated with farmer's participation in management activities.

One of the important findings of this study revealed that irrigation serves as a fundamental tool to enlarge the horizon of farmers' crop choice decision favoring to cultivate a combination of diversified crops. It was observed that combination of cereal, vegetable and cash crop cultivation in the KIDP predominately elicited as the most important crop in the scheme.

Crop choice decision under irrigation agriculture is widely subjected to a serious of household, institutional, social and economic factors. It was primarily attributed to the factors of length of crop maturity period, crop in-home utilization and access to market, as irrigators demand to grow short season crops with a primary concern for home utilization followed by income generation. Certain factors also proved further influential, with the education level, land holding size and input cost regarded by farmers as important which is expected given the markedly profit maximization orientation of agriculture in the area.

One another most important finding of this study apparently indicated that assuring food security in the community is beyond augmenting annual income through irrigation agriculture. As evidenced by the irrigating groups attaining higher income than their counterfactual group, increasing income from irrigation agriculture does not enhance the food security of irrigators in the KIDP. Therefore, unless extra supplementary work is done for the poor, it does not necessarily mean irrigation intervention in itself improves the households' multidimensional food security. Even though *Mecha woreda* is amongst the lists of agriculturally potential areas in the region, one third of the households in the study area were mildly food insecure.

Finally, the study found that in the study area the use of irrigation significantly reduces households' multidimensional poverty. It is no coincidence that households with the best poverty reduction performance have used irrigation agriculture that has complemented advances in other areas of agricultural production. However, there was a problem of targeting the right poor to the project, as evidenced by the higher impact of irrigation on non-irrigators' poverty reduction if they could have irrigated than irrigators. The poverty incidence and poverty intensity in the study area were lower as compared to the 2017 national, rural and regional MPI estimates of Ethiopia. Above all, it should be noted that regardless of access to irrigation, the incidence of poverty among the sample households is still higher.

8.2 Recommendations

This part presents the possible policy recommendations which emanate from the key findings and conclusions drawn. As a result, in line with the findings of the study, the following policy implications which could benefit smallholder producers are drawn.

1. In collaboration with the water committees and the regional water authority, the KIDP office should adopt scientific irrigation scheduling modalities and modern technologies to the scheme. The adoption should consider crop water need, nature of the soil, availability of water and critical periods in the growing season by applying fair and equal water distribution throughout irrigation reaches, as failure to consider these elements may result in subsequent crop failures. For example, sprinklers which are used to apply water to the soil similarly as a natural rainfall and spread uniformly over the land surface could be appropriate to the area.
2. Farmers should be encouraged to participate equally in various collective activities as the failure or success of a particular activity affects the performance of the scheme. To enhance the users' participation, the scheme's administrative body should intervene by focusing on the identified determinants of participation such as infrastructure refurbishments, awareness creation through meetings and training, and supplying credit and regular extension services.
3. The local government and experts should have to focus on the positive factors that guide farmers to cultivate combinations of crops because there are still cereal crop-only and vegetable-only producers in the KIDP. For example, access to education and water related training, and market access were encouraging factors for crop diversification so that irrigators should be supported in this regard to maximizing their agricultural return.
4. The growing interest of policymakers in promoting irrigation, particularly in rural areas should not stick only to increase household income but also, they have to plan ways how the generated income guarantees household's multidimensional food security. The increasingly generated income from irrigation activities should enable households to access sufficient, safe and nutritious food that meets their dietary food preferences for an active and healthy life. Therefore, before the poor can take advantage of irrigation, they need to be provided with education and awareness creating training about nutritional food, food

variety and food security so that they will use the generated income to assure their food security.

5. Moreover, special attention has to be given for mildly food insecure households in the study area. Since the majority of households in the area were mildly food insecure, it could be easy to transit them to be food secure if they are supported in programs supplied with improved and enough agricultural inputs with education and training programs to maximize agricultural production and food security.
6. So as to excel the impact of irrigation on rural poverty reduction, the national water and irrigation authority should give first line attention for the detail poverty analysis to identify where the technology is most demanded to support the right poor.
7. Access to irrigation agriculture should also be accompanied by the provision of institutional support services, modern technologies and complementary production inputs. For example, creating awareness for farmers on effective and efficient utilization of the scheme, access of updated irrigating technologies, infrastructure, credit and farm inputs such as improved seed, fertilizer and insecticide are of great importance to reduce poverty.

8.3 Areas for Future Research

The study is complete given its objectives and delimitations. But the study could have more comprehensive had some of its delimitations been relaxed and some limitations been avoided. Some of the delimitations of the study and the potential areas for future research are discussed as follows.

a) Crop wise field water application

The study has assessed the general situation of water sharing mechanisms applied in the scheme. Its focus was to indicate how water is divided among beneficiary households at a plot level. As a result, it was delimited to cover the idea of crop-wise irrigation water application. The study indicated that problems related to water allocation in the KIDP seems complicated and detail. Thus, studying the issue of crop-wise water application (irrigation scheduling) could help better understand the trend of detail field water application methods. Perhaps, studying this issue and indicating the gaps could be important for irrigation users to have good agricultural returns because application of crop-wise water requirement and stage-wise water requirement data in the field might better help them to grow crops appropriately. It might be also a good indication for policymakers to set the most feasible water allocation mechanisms. Given that this study did not capture the issue in detail, future research should inquire about it in detail and investigate the contributions to production and productivity.

b) Income nexus multidimensional food security

The issue of food security considers various dimensions such as availability, accessibility and utilization of food. The studies carried out on food security impact of irrigation in the literature applied one dimensional (i.e., monetary) food security measurement and highly pronounced that if a household's income could increase using irrigation agriculture, then irrigation has positive and significant impact on food security. However, this study employed multidimensional food security index measurement and estimate the impact of irrigation on food security and on income separately. Unexpectedly, the impact of irrigation on food security was found to be insignificant, but was significant on income. The mismatch between the finding of this research and the findings in the literature might be arisen either from measurements variation or missing of considering detail issues in using income as a proxy to food security. It is, therefore, highly recommended that the findings of this research can be used as a spring board for future investigations on income nexus multidimensional household food security.

c) Wealth accumulation

In line with evaluating the impact of irrigation on poverty, the study found that majority of irrigation users were deprived in durable asset index. This haphazardly indicates that the culture of households' wealth accumulation is not strong. And the literature indicated that changing the generated income to durable asset (wealth) is a problem of irrigation users in many schemes. Furthermore, the impact of irrigation on wealth accumulation was not made in the KIDP. Therefore, good policy implications would be emanated if future researches focus on the wealth accumulation status of irrigation users.

d) Market value chain analysis

As far as the interviews and informal discussions with beneficiary households concerned, seemingly, there was no clear and strong market value chain between the producers and consumers. Therefore, future research could take in to account to better understand the market value chain and determinants of strong market linkage as well as access to market in the KIDP.

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Annexes

Annex 1: Irrigator and adjoining rain-fed Kebele lists

Kebele	**Number of households**	**Position in the scheme**
Kudmi	1885	Upper
Ambo Mesk	1686	Upper
Tagel Wodefit	1558	Middle
Enamirt	1130	Middle
Enguti	1371	Middle
Kolela	552	Middle
Awuta	1706	Middle
Amarit	2667	Lower
Ediget Behibret	1367	Lower
Enashenifalen	1827	Non-user
Kurt Bahir	2091	Non-user
Abiyot Fana	2262	Non-user
Rim	1316	Non-user
Sira betegibar	623	Non-user
Midre genet	1019	Non-user
Bachima	1830	Non-user
Total	24890	

Source: KIDP office, 2017

Annex 2: Sample household distribution across selected sample kebeles

Sample kebele	**Sample HHs**	**Percentage**	**Position**
Kudmi	56	14	Upper catchment
Tagel Wodefit	46	12	Middle catchment
Enguti	40	10	Middle catchment
Amarit	78	20	Lower catchment
Enashenifalen	65	16	Non-user
Kurt Bahir	40	10	Non-user
Abiyot Fana	70	18	Non-user
Total	395	100	

Source: own sampling technique

Annex 3: Multidimensional household food security generic questions with correspondent dimensions.

No,	Var.NAME	Questions	Measurement	Dimension
1	NOEAT	In the past 30 days, how often did you or any HH member have to go a whole day without eating?	HFIAS/ HHS	Quantity
2	SLPHUN	In the past 30 days, how often did you or any HH member go to sleep at night hungry?	HFIAS/ HHS	Stability
3	NOFOOD	In the past 30 days, how often was there ever no food in your HH?	HFIAS/ HHS	Quantity
4	SKIPEAT	In the past month, how often has the HH had to skip entire days without eating?	CSI	Quantity
5	SENDBEG	In the past month, how often has the HH had to send HH members to beg?	CSI	Quantity
6	SENDEAT	In the past month, how often has the HH had to send HH members to eat elsewhere?	CSI	Quantity
7	PULSE	In the past month, how often has the household eaten any pulses?	FCS/HDDS	Quality/diversity
8	GRAIN	In the past month, how often has the household eaten any food made from grain?	FCS/HDDS	Quality/diversity
9	EATSEED	In the past month, how often has the HH had to consume seed stock held for next season?	CSI	Quantity
10	WILD	In the past month, how often has the HH had to gather wild food, hunt, or harvest immature crops?	CSI	Quantity
11	FDCRED	In the past month, how often has the HH had to purchase food on credit?	CSI	Quantity
12	BORROW	In the past month, how often has the HH had to borrow food, or rely on help from a relative?	CSI/rCSI	Quantity
13	NOTWNT	In the past 30 days, how often did you or any HH member have to eat foods you did not want to eat?	HFIAS	Acceptability
14	LIMVAR	In the past 30 days, how often did you or any HH member have to eat a limited variety of foods?	HFIAS	Quality/Diversity
15	PREFER	In the past 30 days, how often were you or any HH member not able to eat the kinds of foods you preferred?	HFIAS	Acceptability
16	FWRMEAL	In the past month, how often has the HH had to reduce the number of meals eaten in a day?	CSI/rCSI	Quantity
17	LMTPORT	In the past month, how often has the HH had to limit portion size at mealtimes?	CSI/rCSI	Quantity
18	WORRY	In the past 30 days, how often did you worry that your HH would not have enough food?	HFIAS	Stability
19	SAFS	Self-assessed food security during past 30 days	SAFS	Stability
20	DAIRY	In the past month, how often has the household eaten any dairy products?	FCS/HDDS	Quality/Diversity
21	EGGS	In the past month, how often has the household eaten any eggs?	FCS/HDDS	Quality/Diversity
22	MEAT	In the past month, how often has the household eaten any meat, fish?	FCS/HDDS	Quality/Diversity
23	FRUIT	In the past month, how often has the household eaten any fruits?	FCS/HDDS	Quality/Diversity
24	VEGET	In the past month, how often has the household eaten any vegetables?	FCS/HDDS	Quality/Diversity

Source: adapted from Maxwell *et al.* (2013).

Annex 4: Algorithmic classification of household food security, in a single, unique category according to their response

No.	Name	1(best)	2	3	4 (worst)
1.	NOEAT				
2.	SLPHUN				
3.	NOFOOD				
4.	SKIPEAT				
5.	SENDBEG				
6.	SENDEAT				
7.	PULSE				
8.	GRAIN				
9.	EATSEED				
10.	WILD				
11.	FDCRED				
12.	BORROW				
13.	NOTWNT				
14.	LIMVAR				
15.	PREFER				
16.	FWRMEAL				
17.	LMTPORT				
18.	WORRY				
19.	SAFS				
20.	DAIRY				
21.	EGGS				
22.	MEAT				
23.	FRUIT				
24.	VEGET				

Source: adapted from Maxwell *et al.* (2013).

Annex 5: Descriptive Statistics in PCA

Variable	**Mean**	**Std. Deviation**	**min**	**Max**
PCNLM	3.191	.984	0	4
AMETING	2.691	1.112	0	4
IDEACONT	2.313	1.245	0	4
ATRNG	1.527	1.416	0	4
REPULWUSE	2.236	1.289	0	4
REPTHFT	2.245	1.301	0	4
REPROFF	2.327	1.328	0	4
REPDSTRN	2.500	1.273	0	4

Source: Own survey data calculation, 2017.

Annex 6: PCA Post estimation test			
Variable	**A**	**B**	
	communality	**Variable**	**communality**
PCNLM	.580	PCNLM	.590
AMETING	.707	AMETING	.735
IDEACONT	.680	IDEACONT	.667
PTRNG	.456	REPULWUSE	.754
REPULWUSE	.755	REPTHFT	.775
REPTHFT	.777	REPROFF	.815
REPROFF	.786	REPDSTRN	.681
REPDSTRN	.665	**Overall**	**0.800**

Source: Own survey data calculation, 2017.

Source: the KIDP office, 2017

Annex 7: Irrigation production profitability of the KIDP in 2016

Type of crop	**Yield/ha**	**Product/qu**	**Total income**	**Net profit**	**Profitability rank**
Wheat	30	150,972	131496612	88268296.00	1
Barley	14	1,825	1186412.50	492817.50	8
Maize	55	19,115	7263533.75	4119709.53	4
Potato	200	90,664	33183024	26446688.80	2
Head cabbage	200	13,921	3480250	2487682.70	6
Tomato	220	14,809	5183062.50	4189193.44	5
Garlic	85	128	255000	233790.00	9
Onion	170	29,346	20542375	17618107.50	3
Paper	22	573	229350	2085.00	11

Annex 8: Probit model Estimates of Propensity Score Matching

```
****************************************************
Algorithm to estimate the propensity score
****************************************************

Estimation of the propensity score

Iteration 0:   log likelihood = -271.22427
Iteration 1:   log likelihood = -247.66537
Iteration 2:   log likelihood = -247.40988
Iteration 3:   log likelihood = -247.40975

Probit regression                                  Number of obs=395
                                                   LR chi2(7) =47.63
                                                   Prob>chi2=0.0000
Log likelihood = -247.40975                        Pseudo R2=0.0878
```

Irrigation	**Coef.**	**Std. Err.**	**z**	**P>z**	**[95% Conf.Interval]**	
AGE	.0066089	.0095604	0.69	0.489	-.0121291	.0253469
EXTENSION	.0326061	.1544424	0.21	0.833	-.2700955	.3353077
FAMSIZE	.1045831	.0354628	2.95	0.003	.0350773	.1740889
EDUYRS	.1089834	.0273541	3.98	0.000	.0553702	.1625965
EXPERIENCE	-.0035468	.0093367	-0.38	0.704	-.0218464	.0147528
GENDER	-.0077952	.1417915	-0.05	0.956	-.2857015	.2701111
PLANDSIZE	.4265171	.1406485	3.03	0.002	.1508512	.7021831
_cons	-1.220631	.352922	-3.46	0.001	-1.912346	-.5289169

Note: the common support option has been selected
The region of common support is [.19495162, .98273199]

Annex 9: The mean value for the independent variables between the treated and untreated respondents before and after matching.

pstest

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct bias	t-test t	t-test p>t	V(T)/ V(C)
AGE	U	42.7	40.474	17.9		1.78	0.077	0 .78
	M	42.785	42.393	3.2	82.4	0.32	0.747	0.72*
EXTENSION	U	.77273	.71429	13.4		1.33	0.185	0.86
	M	.77626	.81735	-9.4	29.7	-1.07	0.286	1.16
FAMSIZE	U	6	5.1829	41.3		4.09	0.000	0.96
	M	6.0228	5.9361	4.4	89.4	0.42	0.676	0.66*
EDUYRS	U	2.0318	1.1029	35.9		3.53	0.000	1.24
	M	2.0365	2.0822	-1.8	95.1	-0.16	0.876	0.66*
EXPERIENCE	U	22.955	20.629	17.8		1.76	0.078	0.94
	M	23.055	23.292	-1.8	89.8	-0.18	0.857	0.76*
GENDER	U	.68182	.66857	2.8		0.28	0.781	0.98
	M	.68037	.73973	-12.6	-348.1	-1.37	0.172	1.13
PLANDSIZE	U	1.0767	.78786	50.5		4.95	0.000	1.29
	M	1.0817	1.0929	-2.0	96.1	-0.18	0.855	0.79

* if variance ratio outside [0.77; 1.30] for U and [0.77; 1.30] for M

Annex 10: Description of the estimated propensity score in region of common support

Estimated propensity score

	Percentiles	Smallest		
1%	.2512057	.1949516		
5%	.2933836	.2251424		
10%	.3342042	.2456936	Obs	394
25%	.4259752	.2512057	Sum of Wgt.	394
50%	.5604194		Mean	.5561578
		Largest	Std. Dev.	.1620769
75%	.6785999	.9412859		
90%	.7590373	.9683129	Variance	.0262689
95%	.8250304	.9705207	Skewness	.1109376
99%	.9412859	.982732	Kurtosis	2.38700

****

Step 1: Identification of the optimal number of blocks Use option detail if you want more detailed output

****

The final number of blocks is 6

This number of blocks ensures that the mean propensity score is not different for treated and controls in each block

****

Step 2: Test of balancing property of the propensity score Use option detail if you want more detailed output

****

The balancing property is satisfied

This table shows the inferior bound, the number of treated and the number of controls for each block

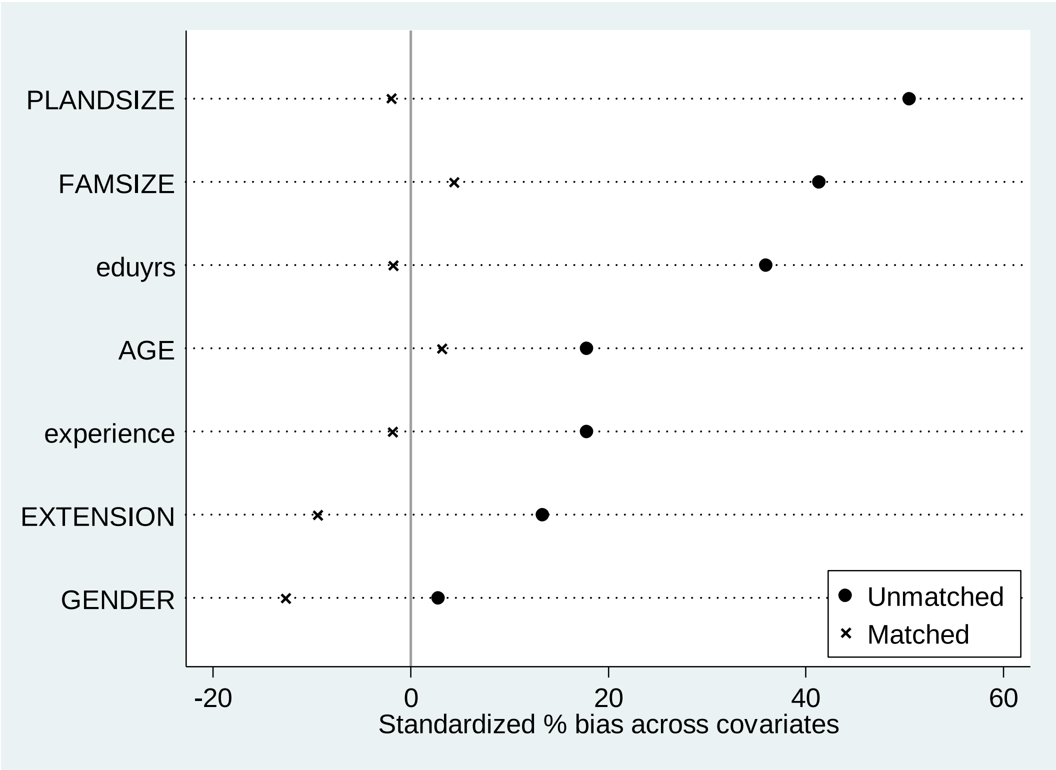
Inferior of block	irrigation use		
of pscore	0	1	Total
.1949516	0	1	1
.2	46	24	70
.4	87	69	156
.6	32	55	87
.7	5	52	57
.8	4	19	23
Total	174	220	394

Note: the common support option has been selected

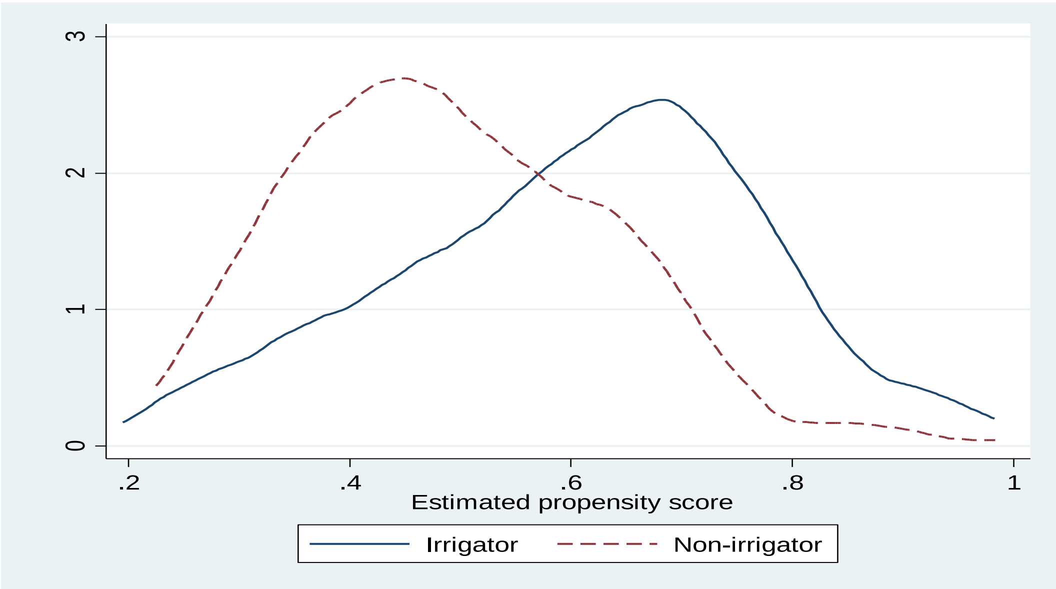
****

End of the algorithm to estimate the pscore

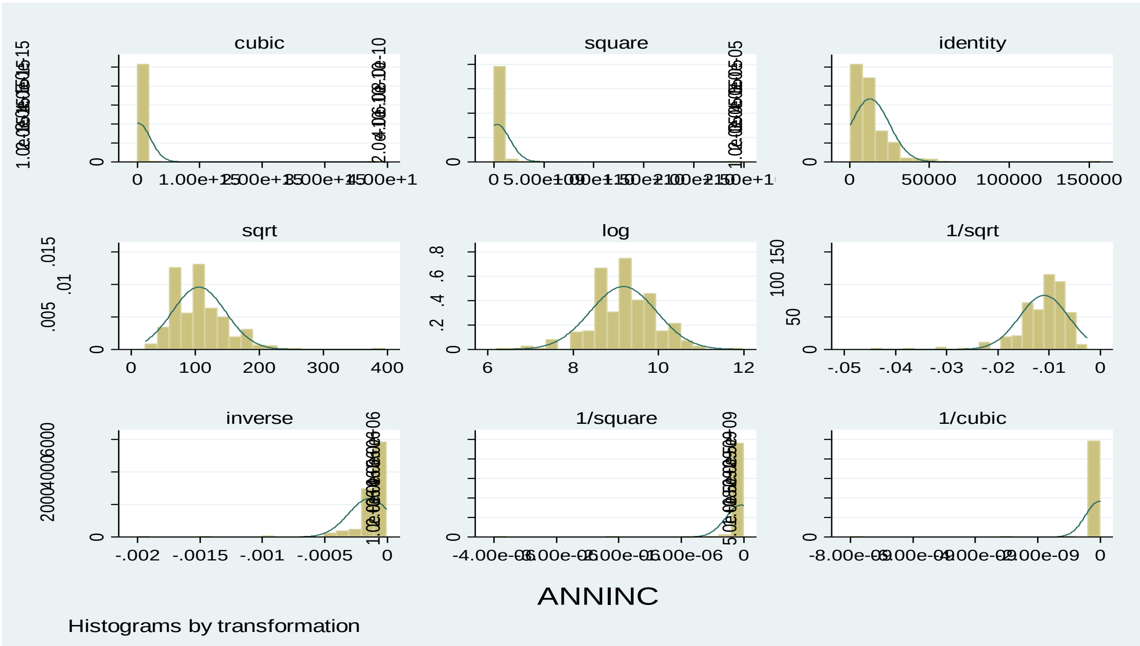
Annex 11: Bias before and after matching



Annex 12: Distribution of propensity scores for the full sample



Annex 13: Normalization of annual income distribution



Annex 14: Contribution of dimensions and indicators to overall multidimensional poverty in %

Dimension	*Mo*	Indicator	*Mo*
Education	24.8	Years of Schooling	14
		Child school attendance	10.8
Health	15.8	Child Mortality	1.3
		Access of health facility	14.5
Living standard	20	Electricity	6.8
		Improved Sanitation	6.9
		Safe Drinking Water	5.7
		Roofing	0.4
Productive assets	39.5	Livestock index	16
		Durable asset	23.5

Source: own household survey

Annex 15: Full information maximum likelihood estimates of the switching regression model

Fitting initial values....

Iteration 0: log likelihood = 37.467027

Iteration 1: log likelihood = 43.233392

Iteration 2: log likelihood = 44.273567

Iteration 3: log likelihood = 44.325711

Iteration 4: log likelihood = 44.326147

Iteration 5: log likelihood = 44.326147

Endogenous switching regression model Number of obs = 395

Wald chi (14) = 69.57

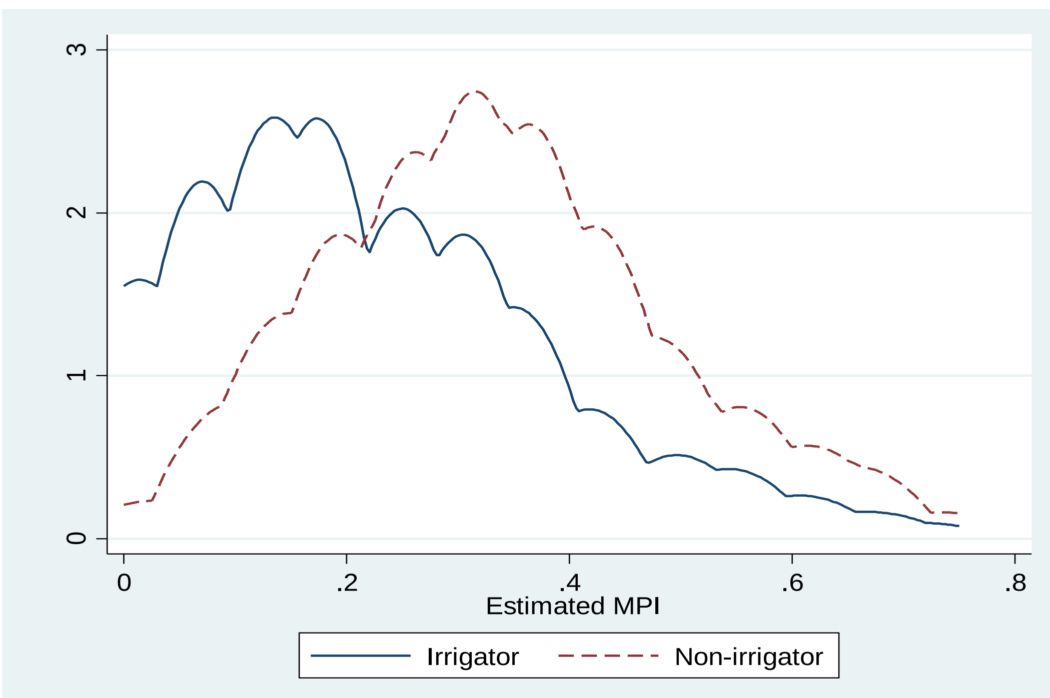
Log likelihood = 44.326147 Prob > chi2 = 0.0000

	Coef.	Std. Err.	Z	P>z	[95% Conf.	Interval]
MPI_1						
farmox	-.0482838	.0150236	-3.21	0.001	-.0777294	-.0188381
experience	-.0037799	.0016295	-2.32	0.020	-.0069738	-.0005861
expctcy	.0868865	.0738159	1.18	0.239	-.05779	.231563
AGE	.0054714	.0019197	2.85	0.004	.0017089	.0092339
Mar_dumy	-.0772848	.0446742	-1.73	0.084	-.1648446	.0102749
CROPLAND	-.1558971	.0359667	-4.33	0.000	-.2263905	-.0854038
logfarminc	.0229254	.0146396	1.57	0.117	-.0057676	.0516184
EDIR	-.0806838	.0339506	-2.38	0.017	-.1472257	-.0141418
educlevel	.0041053	.0040175	1.02	0.307	-.0037688	.0119795
mrktable_dumy	-.0377248	.0288909	-1.31	0.192	-.09435	.0189004
TLANDSIZE	.0356568	.0149058	2.39	0.017	.0064419	.0648717
rcc	-.0597849	.0259509	-2.30	0.021	-.1106476	-.0089221
inputsup	-.0309387	.0248619	-1.24	0.213	-.0796671	.0177897
LENGTHRES	-.0024479	.0012954	-1.89	0.059	-.0049869	.0000911
_cons	.0864968	.1557398	0.56	0.579	-.2187477	.3917412
MPI_0						
farmox	-.0311462	.0118953	-2.62	0.009	-.0544606	-.0078318
experience	-.0020794	.0015136	-1.37	0.169	-.005046	.0008872
expctcy	.205156	.0588635	3.49	0.000	.0897857	.3205263
AGE	.0007856	.0018628	0.42	0.673	-.0028655	.0044368
Mar_dumy	-.0465705	.0750037	-0.62	0.535	-.193575	.100434
CROPLAND	.0702021	.0598437	1.17	0.241	-.0470894	.1874937
logfarminc	-.007601	.0121159	-0.63	0.530	-.0313478	.0161458
EDIR	-.0877891	.0428315	-2.05	0.040	-.1717373	-.0038408
educlevel	-.0056107	.0055475	-1.01	0.312	-.0164836	.0052621
mrktable_dumy	.0448362	.0384814	1.17	0.244	-.030586	.1202583
TLANDSIZE	-.0374916	.0232526	-1.61	0.107	-.0830658	.0080826
rcc	-.0978589	.037295	-2.62	0.009	-.1709559	-.024762
inputsup	.0064018	.026241	0.24	0.807	-.0450296	.0578333
LENGTHRES	-1.59e-06	.0012066	-0.00	0.999	-.0023665	.0023633
_cons	.5312997	.085957	6.18	0.000	.3628271	.6997722
IRRIUSE						
experience	-.0111831	.0099365	-1.13	0.260	-.0306584	.0082922
AGE	.036792	.0114513	3.21	0.001	.0143479	.0592361

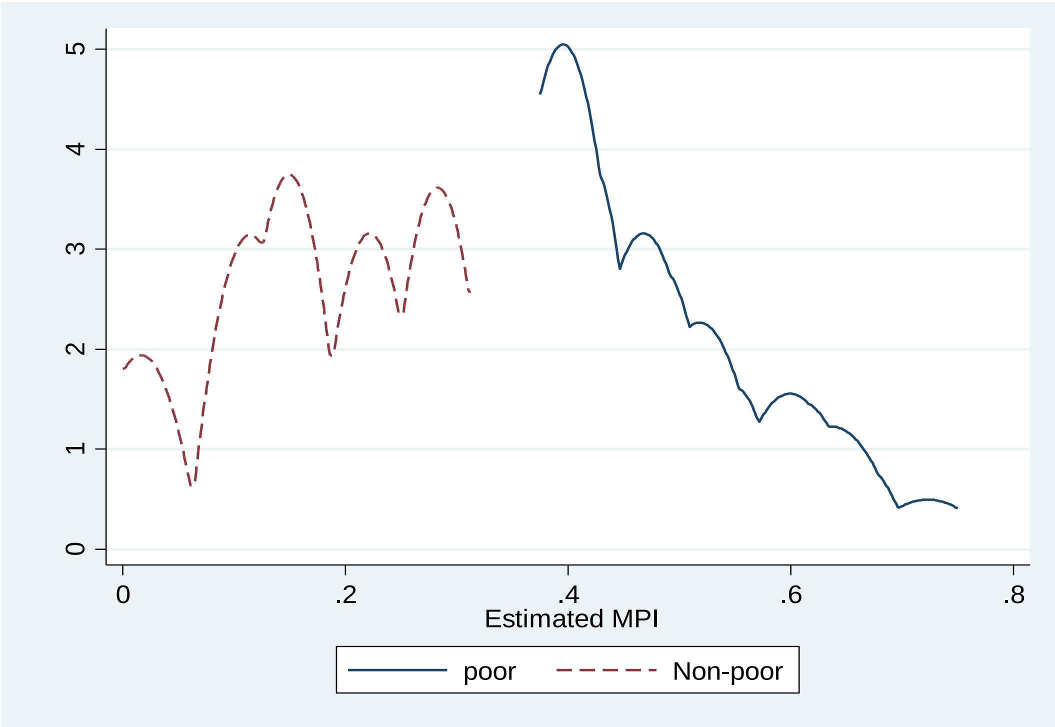
CROPLAND	-1.393873	.2457959	-5.67	0.000	-1.875624	-.9121221
educlevel	-.0719508	.0266974	-2.70	0.007	-.1242769	-.0196248
mrktable_dumy	-.4268198	.1891735	-2.26	0.024	-.797593	-.0560466
TLANDSIZE	.3836364	.1080548	3.55	0.000	.1718529	.5954198
rcc	-.5665021	.1632181	-3.47	0.001	-.8864037	-.2466005
inputsup	-.1168556	.1554647	-0.75	0.452	-.4215607	.1878495
LENGTHRES	-.0154648	.0074171	-2.09	0.037	-.030002	-.0009276
farmox	.018847	.0833975	0.23	0.821	-.1446091	.182303
expctcy	.8652409	.4391376	1.97	0.049	.0045471	1.725935
Mar_dumy	-.8362728	.3314378	-2.52	0.012	-1.485879	-.1866665
logfarminc	.4313043	.0808198	5.34	0.000	.2729004	.5897082
EDIR	-.3187198	.2288532	-1.39	0.164	-.7672638	.1298242
info_ratvm	.3557732	.1152672	3.09	0.002	.1298536	.5816929
_cons	-2.603573	.8208134	-3.17	0.002	-4.212337	-.994808
/lns1	-1.702707	.0622347	-27.36	0.000	-1.824685	-1.580729
/lns2	-1.95388	.0781985	-24.99	0.000	-2.107147	-1.800614
/r1	2.089572	.386723	5.40	0.000	1.331609	2.847535
/r2	.3981885	.3044852	1.31	0.191	-.1985916	.9949685
sigma_1	.1821897	.0113385			.1612685	.205825
sigma_2	.1417231	.0110825			.1215844	.1651974
rho_1	.9698386	.0229764			.869642	.9932975
rho_2	.3783979	.2608875			-.1960214	.759473

LR test of indep. eqns. : chi2(1) = 16.09 Prob > chi2 = 0.0001

Annex 16: MPI score distribution of irrigators and non-irrigators



Annex 17: MPI poverty cut-offs



Annex 18: Household survey questions

Household Survey Questionnaire

<u>Dear respondents</u>:

The objective of this survey is to assess water sharing mechanisms, crop choice determinants and the impact of irrigation on poverty reduction and food security in the Koga irrigation development project area. I would like to primarily inform you that the information obtained will be used for academic purpose; that is, for dissertation research in partial fulfillment for PhD degree in development studies (specialization in rural development) at Addis Ababa University.

Your participation is voluntary, and confidentiality is guaranteed. All replies are anonymous; only summaries of the compiled results will be made public. Thus, I kindly request you to give relevant and reliable information for the provided questionnaire.

For all your cooperation and dedication, I thank you in advance.

Sincerely,

Koyachew Enkuahone
PhD Student at Addis Ababa University, College of Development Studies
Center for Rural Development
Email: koyeenkua1979@gmail.com
Mobile: +251910014141
Addis Ababa, Ethiopia

Section I: Interviewer Administered Questionnaire

Module 1: Demographic information *(for both irrigator and non-irrigator)*			
No	**Question**	**Code**	**Response**
1.1.	Sex	0=Male 1=Female	
1.2.	Marital status	1=Single2=Married 3=Divorced 4=Widowed	
1.3.	Religion	1=Orthodox 2=Muslim 3=Protestant4=Catholic 5=Non follower	
1.4.	Age in years	Write in years	___________
1.5.	Family size	<18 years_________ 19-59 years ______________ >60 years___________	Total __________
1.6.	Educational status	Write the status: ________________________________	
1.7.	Income	Write in birr	
1.8.	What is the Kebele you reside in?	Write the name	
1.9.	For how many years have you lived in the area?	Write in years	
1.10	Land size	-land owned/ha_________ -land rented/leased/ha______	Total size/ha ___________
1.11	Cropped area/ha	________	
1.12	Income/year	Write in birr: _______________________________________	
1.13	Accesses to Credit	0=no accesses 1=small 2=medium 3=high	
1.14	Accesses to Extension service	1=Yes 0=No	
1.15	Are you a member of any social organization?	1=Yes 0=No	
1.16	If your answer is "yes" for question # 1.15, what is the organization in which you are involved as a member?	1=Edir 2=Ekub 3=Mahiber 4=one to five organization 5=water user association 6=any co-operative 7=youth association If others: -______________________________	

Module 2: <u>Irrigation water sharing mechanism questions</u> *(for irrigators only)*

No,	Question	Code	Response
1.	Are you a beneficiary of *koga* irrigation and watershed management project? (*Leave others if not*)	1) Yes 0) No	
2.	If your answer to question 1 is "yes", how were you been targeted to be irrigator?	1) You were geographically located in the boundary 2) The government gave you farm land to replace your land taken by the construction 3) You resettled voluntarily by request of the government 4) You resettled forcefully by the government 5) Selected as an investor 6) Others ________________	
3.	When do you start and end-up irrigating your plot in the production year?	From_____________up to______________ month	
4.	What type of irrigation system are you using?	1) furrow system 2) Side rolls system 3) Center Pivots system 4) Sprinkler 5) if other __________________	
5.	How do you share water with others to irrigate your plot?	1) I use schedule/order set by authors 2) Water is always available and I can use when need arises 3) I get water when I pay 4) If any__________________	
6.	If your answer for #4 is "1", in what time interval you can get water to irrigate your field?	Write the time interval: ____________________________	
7.	In your opinion, how effective is the existing water sharing mechanism across the scheme?	1) Very Good 2) Good 3) Poor 4) Very Poor 5) Neutral	
8.	Do you feel that water is equally distributed among users?	1) Yes 0) No	
9.	How does the mechanism you use to share water is influencing your production?	1) positively influencing 2) Negatively influencing 3) has no influence/my production is not different from the previous one	

10.	If your answer for question 9 is "2", please specify negative influences		
11.	Did you face water shortage? (Leave 9-10 if No)	0) Yes 0) No	
12.	If your answer for #8 is "yes", when do you face water shortage?	Write months: ________________________________	
13.	If your answer for #8 is "yes", how do you decide which crops to irrigate when water is short?	1) Irrigate most stressed crop 2) Irrigate best crops first 3) Ask advice 4) Carry on regardless Other_________________________	
14.	Have you ever involved in conflict to share water?	1) Yes 0) No	
15.	Are you interested if the current way of water sharing is continued?	1) Yes 0) No	
16.	If "NO" what would you suggest?	Write:	
17.	Do you think that the water sharing mechanism has serious drawbacks?	1) Yes 0) No	
18.	If "YES "Can you tell us main ones?	Write:	
19.	In general, how much did you satisfy by the provided irrigation service?	1) Highly satisfied 2) Satisfied 3) Poorly satisfied 4) Unsatisfied 5) I don't know	

20. **How are you participating in the following irrigation management activities?**
(Please rank your participation level by using five-Likert scale value;
0 = never been involved; 1 = low involvement; 2 = average; 3 = high; 4 = very high*)*

	No	**Activity**	**Response**
Labor-based participation	20.1.	Involve in canal maintenance (rebuilt destroyed canal, cut grass, avoid silt etc.)	
	20.2.	Involve in new canal construction	
Financial-based participation	20.3.	Pay maintenance fee	
	20.4.	Pay service fee	
	20.5.	Contribute towards Water User Association	
Participation in decision making	20.6.	Attending meetings	
	20.7.	Contributing ideas in water related issues	
	20.8.	Attending trainings	
Participation in regulation and control	20.9.	Reporting unlawful water use	
	20.10	Reporting theft of irrigation infrastructure	
	20.11	Reporting water leakages /runoff	
	20.12	reporting any infrastructure damages	

Specify if others: ____

21. Factors influencing participation in irrigation management practices.		
No,	**Question**	**Response**
21.1.	How much irrigated land do you own?	Write in ha: ___________
21.2.	What is your annual income from irrigation agriculture?	Write in birr: __________
21.3.	Have you ever paid for any irrigation maintenance cost?	1 = Yes 0 = No
21.4.	If your answer for question 21.3 is "yes" How much do you pay in year?	Write in birr: __________
21.5.	Where is your majority of plot positioned from main canal?	1 = Upper/head 2 = Middle 3 = Tail-end
21.6.	Do you attend water-related meetings?	1 = Regularly 0 = Less regular or not at all
21.7.	Do you think water is equally distributed among users?	1 = Yes 0 = No
21.8.	Are you satisfied with the work of water authority /committees?	1 = Yes 0 = No
21.9.	Have you ever attended irrigation water management trainings?	1 = Yes 0 = No
21.10.	Do you think the system has rigid rule and regulations?	1 = Yes 0 = No
21.11.	Does the system hold participatory approaches	1 = Yes 0 = No
21.12.	Have you ever involved in any water-related conflict?	1 = Yes 0 = No
Specify if others: ____		

22. In your opinion, how does each of the following factors influence the sustainability of KIWSM? *(Please rank the level of influence by using five-Likert scale value; 0* ***= has no influence; 1= low influence; 2 = medium influence; 3 = high influence; 4 = very high influence****)*		
No	**Factor**	**Response**
22.1.	Community perception	
22.2.	Inadequate Maintenance service	
22.3.	Rules and regulations not in place	
22.4.	Rules and regulations not enforced	
22.5.	Management structure and responsibilities	
22.6.	Current government policy	
22.7.	Absence of Professionals and expertise advice	
22.8.	Peace and security (Conflict)	
22.9.	Access of infrastructure problem (store, transport, education, health, etc.)	
22.10.	Competition for water	
22.11.	climate change	

22.12.	Siltation	
22.13.	Run off/erosion	
22.14.	Costs related to irrigation	
Specify if any: ____		

<u>Module 3: Crop Choice Decision Questions</u> <u>*(for both irrigators and non-irrigators)*</u>

1. What is your main livelihood activity? (note: more than one answer is possible)			
No	**Type of livelihood**	**Response code (put ✓)**	**Amount of income/year**
1.1.	farming		
1.2.	Beefing		
1.3.	Dairying		
1.4.	Fishing		
1.5.	Poultry		
1.6.	Honey bee keeping		
1.7.	Daily laboring		
1.8.	Government employee		
1.9.	Small business (shop, tea-coffee, grocery, etc.)		
1.10.	Merchant (crop, tree, chat, livestock, etc.)		
1.11.	Other_________________________		

2. What are the types of crops you grow in your farm?			
No	**Product item**	**Code 1=Yes 0=No**	**Land allocated/ha**
	Cereals		
2.1.	Wheat		
2.2.	Teff		
2.3.	Millet		
2.4.	Barley		
2.5.	maize		
2.6.	Sorghum		
2.7.	Oat		
2.8.	Rice		
2.9.	Other cereals		
Vegetables			
2.10	Ethiopian cabbage,		
2.11	head cabbage		
2.12	Garlic		
2.13	Potato		
2.14	Tomato		
2.15	Carrot		
2.16	Pepper		
2.17	Onion		
2.18	Other vegetables		

Pulses & oil seeds			
2.19	Niger/Noog		
2.20	bean		
2.21	pea		
2.22	Linseed/Telba		
2.23	Groundnut		
2.24	Sesame/Selit		
2.25	Others		
Cash crop			
2.26	Coffee		
2.27	Chat		
2.28	Eucalyptus tree		
2.29	Other cash crops		

3. Crop choice decision determinant factors		
3.1.	How much plot of land do you have?	Write in hectare:_______
3.2.	For how many years do you stay in farming?	Write in years:_________
3.3.	Do you think the crop you grow give more yield than other crops?	1= Yes 0=No
3.4.	Do the crops you grow are marketable at the area?	1= Yes 0=No
3.5.	Do the crops you grow are highly utilized for home consumption?	1= Yes 0=No
3.6.	How much amount of money did spend to purchase inputs (fertilizer, improved seed, pesticide, etc.)	Write in birr: __________
3.7.	Is there enough input supply for the crops you grow?	1= Yes 0=No
3.8.	How do you evaluate the water need of crops you grow?	1=high 2=medium 3=low
3.9.	Do you think the crops you grow are resilient to climate change induced events (pest, disease and drought)	1= Yes 0=No
3.10.	Do the crops you grow are easy to grow?	1= Yes 0=No
3.11.	How much time the crop you grow needs to reach?	Write in moth: _________
3.12.	Have you ever got expertise advice what crop to grow?	1= Yes 0=No
3.13.	Does gov't policy guide you to grow such crops?	1= Yes 0=No
3.14.	Does irrigation controller decide what crop to grow?	1= Yes 0=No
3.15.	Do you think the quality of soil is good to grow?	1= Yes 0=No
3.16.	Do you have access of market for your produce?	1= Yes

		0=No
3.17.	How much time it will take if we walk on foot from your home to the market?	
3.18.	How do you see the supply of water in the scheme?	1=high 2=medium 3=low

Module 4: Food security assessment questions *(for both irrigator and non-irrigator)*

Questions	**Response**
1. In your view how do you assess your food security situation during the past 30 days 1=food secure 2=mildly food insecure 3=moderately food insecure 4=food insecure	
Note: use the following answers to respond questions listed from 2-24 ***1. Never*** ***2. Rarely (1 or 2 times during last 4 weeks)*** ***3. Sometimes (from 3-10 times during last 4 weeks)*** ***4. Often (more than 10 times during last 4 weeks)***	
2. In the past 30 days, how often did you worry that your HH would not have enough food?	
3. In the past month, how often has the HH had to limit portion size at mealtimes?	
4. In the past month, how often has the HH had to reduce the number of meals eaten in a day?	
5. In the past 30 days, how often were you or any HH member not able to eat the kinds of foods you preferred?	
6. In the past 30 days, how often did you or any HH member have to eat a limited variety of foods?	
7. In the past 30 days, how often did you or any HH member have to eat foods you did not want to eat?	
8. In the past month, how often has the HH had to borrow food, or rely on help from a relative?	
9. In the past month, how often has the HH had to purchase food on credit?	
10. In the past month, how often has the HH had to gather wild food, hunt, or harvest immature crops?	
11. In the past month, how often has the HH had to consume seed stock held for next season?	
12. In the past month, how often has the household eaten any vegetables?	
13. In the past month, how often has the household eaten any fruits?	
14. In the past month, how often has the household eaten any meat, fish?	
15. In the past month, how often has the household eaten any eggs?	

16. In the past month, how often has the household eaten any dairy products?	
17. In the past month, how often has the household eaten any food made from grain?	
18. In the past month, how often has the household eaten any pulses?	
19. In the past month, how often has the HH had to send HH members to eat elsewhere?	
20. In the past month, how often has the HH had to send HH members to beg?	
21. In the past month, how often has the HH had to skip entire days without eating?	
22. In the past 30 days, how often was there ever no food in your HH?	
23. In the past 30 days, how often did you or any HH member go to sleep at night hungry?	
24. In the past 30 days, how often did you or any HH member have to go a whole day without eating?	

Module 5: Poverty assessment questions *(for both irrigators and non- irrigators)*

Dimension	Question	Code	Response
1. Education	1.1) There is no HH member who has completed grade 8.	1=Yes 0=No	
	1.2) Is there any school aged child who is not attending school?	1=Yes 0=No	
2. Health	2.1) Is there any child who has died in this year?	1=Yes 0=No	
	2.2) The HH doesn't have access of health center or the center is more than 1hrwalk from your home?	1=Yes 0=No	
3. Living standard	3.1) The HH doesn't use electricity or generator or solar	1=Yes 0=No	
	3.2) The HH has no improved sanitation systems (such as sewers or septic, poor-flush latrines tanks, simple pit or ventilated improved pit latrines) or it is improved but shared with others	1=Yes 0=No	
	3.3) The HH doesn't have access to safe drinking water or the access is found more than a 30-minutes' walk from home round-trip	1=Yes 0=No	
	3.4) The HH has a house thatched by grass/ grass roof	1=Yes 0=No	
	What durable asset does your household owns?	**Put (✓)**	**Quantity**
	beef cattle		
	milk cow		
	breeding bull		
	farm ox		
	goats and/or sheep		

4.	**Durable asset**	Bees		
		equine (donkey/horse/mule)		
		Radio		
		TV		
		Mobile		
		Bicycle,		
		Car		
		Motorbike		
		Bajaj		
		Water pump		
		Insecticide pump		

Annex 19: Key informant interview and Focus group discussion protocols

Section II: Key informant intreview with Koga project administration and woreda agriculture office

Name**:** ____________________________
Age: ______
Marital status: ___________
Name of institution: ________________
Level of Education: ______________
Field of study: ____________________________
Position: _______________________
Length of service: ____________________
Place of residence: ____________________________

Interview questions

1. When and how KIWSM was established?
2. How irrigators were targeted to be a beneficiary from the scheme?
3. How farmers share water to irrigate their plot? What are the strategies, approches,methods and modalities to share wateramong beneficiaries?
4. Could you explain the administrative structure of the KIWSM?
5. How farmers are organized to use the system effectively?
6. What crops are you recommending farmers to grow? Why?
7. What are the tasks in which experts and farmers are expected to participate in irrigation management?

8. In your opinion, what are the challenges that could be a triat for the sustainability of the system? (eg. Management problem, water shortage, conflict, drought………)
9. Could you explain the measures that have been taken to reduce the challenges?

Key informant intreview with seleted farmer households

1. Do you feel happy by being the beneficiary of the service?
2. How do you evaluate the adeuacy of the service?
3. What are the benefits that you get from the project?
4. Do you think that the projet helps you to reduce your level of poverty?
5. How do you assess your poverty level just after using the service?
6. What could you suggest for the betterment of the projects future service?
7. What are the challenges/problems in using the project?

Section III: FGD interview guides for irrigator and non-irrigator groups

1. How the people perceive the situation of food security in the locality?
2. Do the people have a habit of buying food items in the local markets in view of assuring food security in their home? (e.g., egg, meat, vegetables, fruit etc.)
3. Do you think that the households use the income generated from different sources to buy additional food items?
4. Is there any time in which households faced a considerable food short fall in this year?
5. How do you assess the food security status of households in the locality?
6. Do you think that the koga irrigation development project assists the beneficiary households to earn more income than before?
7. What the households allocated for the generated income?
8. How do you compare the food security status of irrigators with non-irrigators? Do you feel that households using irrigation are better of food secure than non-irrigators? why?