Addis Ababa University (Since 1950)

COLLEGE OF SOCIAL SCIENCE

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

Assessment of surface water resource and irrigation practices in Gudo Beret Kebele, Amhara region, Ethiopia

By

Tigist Birhanu

November, 2016

Addis Ababa

Assessment of surface water resource and irrigation practices in Gudo Beret Kebele, Amhara region, Ethiopia

MA Thesis Submitted to the School of Graduate Studies of Addis Ababa University

By

Tigist Birhanu

In Partial Fulfillment of the Requirement for the Degree of Master of Art in Geography and Environmental Studies

Thesis Advisor: Asmamaw Legass (PhD)

November, 2016

Addis Ababa

Addis Ababa University

College of Social Science

This is to certify that the thesis prepared by Tigist Birhanu, entitled: Assessment of surface water resource and irrigation practices in Gudo Beret Kebele, Amhara region, Ethiopia for the Degree of Master of Arts in Geography and Environmental Studies with Specialization in GIS and Remote sensing.

Signed By the Examining Committee:

Advisor ______________________________ Signature ____________ Date _____________

External examiner ______________________ Signature ____________ Date _____________

Internal examiner _______________________ Signature ____________ Date _____________

____

Chair of Department of Graduate Program Coordinator

ACKNOWLEDGMENT

First and foremost, I would like to thanks my almighty Lord and his mam. Secondly, I am indebted to my advisor Dr. Asmamaw Legass for his advice and sharing his valuable time and ideas.

My special thanks go to Addis Ababa University female and disability scholarship, given to me full sponsorship. I also express my gratitude for Dr. kindu Mekonen and Dr. Luelseged Tamene for their advice, guidance and encouragement. I am also indebted my family for their patience.

This research was undertaken with support from Africa RISING, a program financed by the United States Agency for International Development (USAID) as part of the United States government' Feed the Future initiative. The content is solely the responsibility of the author and does not necessarily represent the official views of USAID or the U.S. Government or that of the Africa RISING program. Africa RISING is aligned with research programs of CGIAR.

TABLE OF CONTENT

Contents **page**

LIST OF TABLE

LIST OF FIGURE

LIST OF ACRONYMS

Africa RISING	Africa Research in Sustainable Intensification for the Next Generation
DA	Development Agent
DEM	Digital Elevation Model
GIS	Geographic Information System
ILRI	International Livestock Research Institution
MoWR	Ministry of Water Resource
PALADIS	Prototype for Assisting Rational Activities in using Images from Satellites
RS	Remote Sensing
SSI:	Small Scale Irrigation
WEDITFC	Water and the Environment Development Issues for the Twenty-first Century
W/ro	‘woyzero’
WUC	Water Use Cooperatives
WW	World War

ABSTRACT

Ethiopia is mainly an agrarian nation and the rainfed system has always played a central role in supporting its society. Agriculture is the core driver for Ethiopia's growth and long-term food security. Cultivable land area of the country is estimated to be between 30 - 70 million hectares. Currently, some estimates show that only 15 million hectares of land is under cultivation. From the existing cultivated area only about 4 to 5 percent is irrigated. The development of irrigation and agricultural water management thus holds significant potential to improve productivity and reduce vulnerability to climactic volatility in the country. Though Ethiopia has abundant water resources, its agricultural system does not yet fully benefit from the technologies of water management and irrigation. In mixed crop–livestock systems, irrigation can increase crop yield and livestock feed supply through increased crop productivity and residues of food–feed crops. Irrigation also serves as a buffer against drought. GISs and simulation models have contributed to the identification and evaluation of potential solutions to water resource problems during the past decade. Understanding the water resource potential of an area can help devise mechanism for efficient use and maximize benefits while minimizing potential conflicts. GIS and hydrological models can be used to understand the spatial dynamics and dynamics and distribution as well as determinants of water resources within landscape. The main objective of this research is to assess the water resources potential and examine major constraints of the present water resource management and irrigation practices in the Gudo Beret area of the North Shewa Zone of Amhara Regional State. Specific objectives include: Analysis of surface water resources, land use/cover types and irrigable area; identify the constraints of irrigation and water management practices; examine the current policy and by-laws related to irrigation water management and examine the gender and nutrition aspect of small scale irrigation practice.. Relevant spatial data were gathered from high resolution satellite image (PALADIS), soil depth base map, topographic maps and ground survey and GPSs. Non-spatial data were acquired through interview, questionnaire, written sources. Simple random sampling has been employed to select sample irrigation scheme and sample respondents. Analysis of results shows that five rivers and nine springs are available in the study area. The study also identifies six major types of land use/cover (i.e. bare land, built up, farm land, forest, grass land and water bodies). Forty percent of the farm and grass land and 29% of total area were irrigable land. The most important irrigation related constraints observed include seasonal water shortage, unavailability and less utility of technologies, limited market and absence of irrigation canal to save water loss. Local communities have good institutional by-law to govern water use and irrigation scheduling as well as conflict resolving methods. Also in the study area participation of women in irrigation farming has increased by 29.7% within ten years. This could both improve food security and income and also buffers crop failure due to drought. There is also a possibility of improvement in human and livestock nutrition as irrigation facilitates diversification.

Key words: Water resources, management, irrigation, agricultural technologies, GIS, Gudo Beret

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

The majority of the Ethiopian populations are mainly agrarian societies who largely depend on rainfed farming as a major source of livelihoods. However, the lag of agricultural production to keep pace with population growth lead to chronic malnutrition and hunger, and periodic crises induced by drought (Negash, 2004). The Cultivable land of the country is estimated to range from 30 - 70 million hectares. However, it is only 15 million hectares of land which is currently under cultivation (Sleshi, 2010). Due to high rainfall variability and climate change, supplementing the rainfed agricultural system in the country through irrigation is an essential option. Investing on irrigation agriculture is considered as one of the key factors in the development of the Ethiopian agriculture (MDRICRI, 2011). Irrigation is an important intervention especially in drought prone areas as it serves as an insurance against rainfall shortage or variability. It helps to reduce uncertainties of climate change and its impact on agricultural practices. From the same land size, agricultural production can be improved by two or more times through irrigation per year (Avinash Kumar, et al., 2014). Therefore, irrigation agriculture has the potential to reduce spatial and temporal yield variability rather than only depending on rainfed crop cultivation (Ben, 2003)

Irrigation has a very old history especially in some parts of the country like Konso area (Rahel, 2008). However, these practices were traditional and covered small geographical area. Large-scale water development projects both for agricultural production and power generation purposes were constructed at the end of the 1950s (Berhanu and Peden, 2002). The contemporary irrigated lands of the country only accounted from 4-5% (640,000 hectares) of the existing arable lands. These irrigation schemes vary widely in size and structure, from micro irrigation (RWH), to river diversion, pumping, small or large dams (Sleshi, 2010). However, significant portions of cultivated lands are not under modern irrigation (Sleshi, 2010). As a result, the sectors contribute little to the economic development of the country. In addition, the development of irrigational agriculture in Ethiopia is still at its infancy stage (MANRMD, 2010).

Although Ethiopia has relatively abundant rainfall and water resources, its agricultural practice does not fully benefit from the water resources and development of irrigation technologies (Sleshi, 2010). Irrigation water management primarily aims to properly managing the volume and frequency of irrigation water applied to crops, so as to meet the food crop demand of the people. Monitoring irrigation water resource also helps in addressing water quality constraints, and efficiently use water resource (MDA, 2015).

Before launching irrigation schemes, there will be a need to evaluate the existing practices and suitability of the area for irrigation practice. Water resource in this research refers to the water available or made available for sufficient use and good quality at a given location over a period of time appropriate for an identifiable demand (WMO, 2012). Water resources assessment is the determination of the sources, extent, dependability and quality of water for their utilization and control. Such analysis requires spatial and socio-economic data at multiple scales. Geographical Information System (GIS) and simulation models have contributed to the identification and evaluation of potential solutions to water resource problems during the past decade (Avinash Kumar, et al., 2014). As GIS is a computerized system that facilitates data entry, analysis and presentation as well as integration of different layers of data (Paul and Chosen, 2001), it can help in generation of irrigation water demand map by modelling water requirement considering crop type and soil and climate biophysical data (Avinash Kumar, et al., 2014). It also has capability to improve planning and decision making for water management (Eltaib, et al., 2004).

1.2 Problem statement

Ethiopian agriculture is mainly dependent on rainfed systems. With increasing climatic variability and changing, it is highly probable that the rainfed agriculture of Ethiopia will be highly vulnerable to drought and flooding (Sleshi and Mekonen, 2011).

Irrigation is necessary to minimize the impact of rainfall variability and in growing a number of annual crops, perennial and commercial crops with control regulated water supply throughout the year (Avinash Kumar, 2014). Now a day, many irrigation infrastructure projects are constructed in different parts of the country by government and non-government organizations. However, smallholder farmers are not still able to achieve food security and reduce poverty. So, by progressively increasing irrigational infrastructures and providing special attention to the scheme, it would be possible to livelihoods of the local people (Sleshi and Mekonen, 2011)

Generally in many parts of Ethiopia, farmers are not appropriately using irrigation technology and could not commonly achieve in improving food security and income unless improved irrigation water management strategies are designed. The irrigation schemes in Gudo Beret area have faced various challenges including poor water use efficiency; cultivating low value crops and practicing inefficient agronomic practice. Even though there was an attempt to establish irrigation project in Gudo Beret and the surrounding areas, the achievements are far below the expectations. Therefore, this research attempts to assess the challenges and opportunities of irrigation practices of Gudo Beret kebele to contribute in improving the food security of the local people.

1.3 Objectives of the study

❖ General objective

The general objective of this research is to generate information on small scale irrigation activities that would support as an input for planning and academic purposes.

❖ Specific objectives

The specific objectives of the study include:

- Analysis of surface water resources, land use/cover types and irrigable area
- Identify the constraints of irrigation and water management practices.
- Examine the current policy and by-laws related to irrigation water management.
- Examine the gender and nutrition aspect of small scale irrigation practice.

1.4 The scope of the study

There are many small scale irrigation schemes in Gudo Beret with large areal coverage respect to and large number of users. The total irrigated area of kebele was large to manage with time, accessibility and resources. The researcher defined the area coverage of irrigated farms align with the Africa RISING project activities.

Based on the preliminary survey of the study area, the existing water supply for the irrigation schemes is from two natural water sources; spring and river. Some of the communities that use irrigation water are organized under water user's cooperatives while some are not. The Mush, Weynabchu and Feleku irrigation schemes are selected for this specific study.

1.5 Significance of the study

This study has generated the following outputs that could be source of information for development sectors, and researchers and academic institutions.

1. Maps of land use/cover type, existing water resource and irrigated/ irrigable areas of study area.

2. Detailed information on irrigation technologies and water management of the study area.

3. Information on policy, institutional and governance that can facilitate efficient irrigation water management.

4. Suggestions on how to resolve conflicts between water users and non-beneficiaries.

5. Information on gaps for further study.

1.6 Organization of the Thesis

The thesis consist of seven chapters, Chapter one discusses the background information of the study which include introduction, statement of the problem, objectives, scope and significance of the study.

Chapter two provides a brief review of literature with emphasis on development/use of irrigation water and management in Ethiopia. Besides, it covers institutional arrangement and irrigation policy in the country, major consideration in the selection of irrigation system, contribution of irrigation and role of GIS in water resource management.

Chapter three highlights the physical and socio economic characteristics of the study area. Data sets used in the study, their sources and methods of collection and analysis are also described in this chapter.

Chapter four discusses GIS-based analysis of available water resource, land use/cover and.+ irrigable area.

Chapter five presents and discusses results. This chapter mainly identifies water use, management and technology constraints in three selected irrigation scheme.

Chapter six examines current policies, by-laws and irrigation in relation to gender and nutrition.

Chapter seven presents the main conclusions drawn from the study and recommendation proposed for future consideration.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Irrigation, water resource use and management

Water is one of the natural resources that play a critical role to sustain livelihoods. It also plays a significant role in improving food security and household income. Water is employed to generate power for use in industries in urban areas. In the developed countries, water is important asset for the leisure industry (Dessalegni, 1999).

Water is the most important input for agriculture production in an irrigated and rainfed farming systems. Irrigation can be defined as replenishment of soil water storage in plant root zone through methods other than natural precipitation (ICID, 2015).

Irrigation water management primarily aims to control the volume and frequency of irrigation water applied to crops, so as to meet crop needs while conserving water resources. Irrigation water management involves an array of methods to reduce water use (MDA, 2015). The goal of irrigation management is to use water in the most profitable way at sustainable production levels. For production agriculture this generally means supplementing precipitation with irrigation (OMICS, 2015).

Irrigation water has been instrumental in feeding the populations of developed and developing countries in the last 50 years. Irrigation has increased food security and improved living standards in many part of the world. Irrigation leads to increased land productivity. Irrigation has increased food production and leads to higher land productivity and land values and irrigation expansion increased employment opportunities, high incomes and improve flood control. Globally 40 percent of food is produced on irrigated land which makes up only 17 percent of the land being cultivated (Karina, 2007).

Ethiopia has potential land for irrigation between from1.0 to 3.5million hectares. However, only 5-10% is estimated to be currently irrigated (Rahel, 2008). The imperial government in the 1950s took the first initiative in water resource development. Large-scale water development projects were constructed at the end of the 1950s. These developments were concentrated in the Awash Valley as part of the agro-industrial enterprises development initiative. Water resource development at that time gradually expanded to the Rift Valley and the Wabi Shebele basin. The government's focus of water resource development was on large-scale and high technology water projects. At the beginning of the 1970s, about 100 thousand hectares of land was estimated to be under modern irrigation in Ethiopia, about 50% of which was located in the Awash Valley (Berhanu and Peden, 2002).

As CHF L-SAP (2010) report indicates, large-scale irrigation programs and related technologies are relatively well known in Ethiopia, and the government actively promoted these schemes during the 1970s and 1980s. However, during the 1990s many irrigated state farms were abandoned and investment in large-Scale and medium-Scale schemes stagnated. At the same time, there was a corresponding expansion of small-scale communal irrigation schemes. Until recently there has been relatively limited government investment in improving these traditional small-scale irrigation schemes or in expanding modern schemes either through providing incentives to encourage private sector involvement, or through government research and extension programs. The government's Water Sector Development Strategy (2002) and Plan for Accelerated and Sustained Development to End Poverty (PASDEP), 2005/6-2009/10 emphasizes the importance of irrigation development in stimulating rural economic growth and development, and ensuring long-term food security, and sees further development of small-scale irrigation and water harvesting, along with agricultural research, as playing a significant role.

The current irrigation schemes development of Ethiopian covers about 640,000 ha across the country. These irrigation schemes vary widely in size and structure, from micro irrigation (RWH), to river diversion, pumping, and small or large dams. These schemes can be subdivided into small, medium and large scale. The small scale irrigation (SSI), which is often community based and traditional methods, cover less than 200 hectares. Examples of SSIs include household based RWH hand dug wells, shallow wells, flooding (Spate), individual household based river diversions and other traditional methods. The medium scale irrigation (MSI), which is community based or publicly sponsored, cover 200 to 3,000 hectares. Examples of MSIs include the Sille, Hare and

Ziway irrigation schemes; the large scale irrigation (LSI) covers more than 3,000 hectares, which is typically commercially or publicly sponsored. Examples of LSIs include the Wonji, Shoa, Methara, Nura Era and Fincha irrigation schemes (Sleshi, 2010).

2.2 Contribution of irrigation for gender and nutrition

There are significant gender differences in water use, access and management. It helps to explain why some cultures, societies or communities are more successful than others to manage water (CAP-NET, GWA 2006). Women and men have distinct responsibilities in using and managing water and water systems. In most societies, women and girls collect every liter of water for cooking, bathing, cleaning, maintaining health and hygiene, raising small livestock and growing food. Rural men need water for irrigation and livestock rearing, but women often care for the milk of cattle and young animals. They also oversee family health. Because of these differing gender roles, women and men have different stakes in water use (UNDP, 2002).

Although women's tasks in environmental management vary according to region, age, socio-economic class, caste and vary within families, many women in rural areas have to go far to fetch water. They spend up to a day's task fetching water while many urban women have to wait long queuing for water. Women further play a key role in agriculture, livestock, forestry and fisheries. Depending on local customs and circumstances, they may be the only farmer in the household, take responsibility for specific crops or subsistence farming, or they may take responsibility for specific farming tasks such as weeding and transplanting (Saskia et al., no date).

Research on gender and water relationship has largely focused on particular elements, such as the division of tasks and labor between men and women, rights and access to water and women's participation in decision making through their involvement in water management organizations (Floriane, 2012).

Irrigation provides a powerful management tool against the vagaries of rainfall and makes it economically attractive to grow high-yield crop varieties and t apply adequate plant nutrition as well as pest control and other inputs, thus giving room for a boost in yields. Irrigation is crucial to the world's food supplies. The availability of water confers opportunities to individuals and communities to boost food production, both in quantity and diversity, to satisfy their own needs and also to generate income from surpluses (FAO, 2003). Irrigation increase food production and availability. Increased food availability is likely to result in better nutrition, though this might not always be the case. Other factors such as food access and utilization are also important determinants of food security and related nutrition outcome (Berti, et al., 2003).

The use of irrigated agriculture enables crop production during the dry/lean season, which increases the number of harvests per year and leads to increased yields and crop diversification. In Ethiopia, farmers using irrigation systems produced crops twice, and sometimes even three times per year (Aseyehegn, et al., 2012 in Domenech & Ringler, 2013).

Domenech & Ringler (2013) concludes that irrigation interventions can improve nutritional outcomes through increased productivity and availability of food supplies and improved diet (in quantity and quality). Irrigation interventions on food security and dietary diversity, which are important factors for children`s development. Nutritional gains can have positive effects on height-for-weight ratios, morbidity, and biochemical/clinical indicators and thus can have beneficial, long-term effects on health. Even if irrigation interventions are likely to improve the diets and nutrition of rural communities, some exceptions are also found when irrigation systems lead to mono-cropping or when unsafe water is used for irrigation.

2.3. Types of Irrigation System

2.3.1. Surface irrigation method

In surface (furrow, flood or level basin) irrigation systems, water moves across the surface of agricultural lands, in order to wet it and infiltrate into the soil. Surface irrigation is often called flood irrigation when the irrigation results in flooding of the cultivated land (Chisholm and Hugh, 2016). Surface irrigation uses gravity to distribute water over the field. Water flows from an area of higher elevation downhill to irrigate all the crops. Unless the land is naturally sloped, this form can be very labor intensive

(Amanda, 2003). As indicate in the (https://www.totaleden.com.au), it is also one of the oldest methods, but is not as efficient as some other options, because there is a tendency to use too much water in order to saturate crops.

2.3.2. Drip irrigation system

Drip irrigation uses a system of tubes to pump water throughout the field. It delivers water droplets directly to the roots of plants (Amanda, 2003). Drip irrigation is also known as trickle irrigation, functions as the name suggests. In this system water is delivered at or near the root zone of plants, drop by drop. This method can be the most water efficient method of irrigation as it minimizes evaporation and runoff. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation, and is also the means of delivery of fertilizer (Chisholm and Hugh, 2016). However, care should be taken not to let the drip system operate for too long, or you could experience a situation in which water moves below the root zone and over saturates the soil (https://www.totaleden.com.au).

2.3.3. Sprinkler irrigation systems

In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. A system utilizing sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a solid-set irrigation system (Chisholm and Hugh, 2016). Drip irrigation pipes a set amount of water to the fields, and then sprays this directly over the crops with high pressure sprinklers. The amount of water can be closely controlled, which is a huge benefit (https://www.totaleden.com.au). Sprinkler irrigation involves a system of pressurized tubes that expel water onto crops. Variations include rotary irrigation, central pivot and lateral move irrigation. Rotary irrigation in which the sprinkler system whirls around, applying the water in a circular motion; the central pivot is just like when you pivot a car, or turn while on foot, these sprinklers change directions to water the entire field. The sprinklers are mounted on mechanical tracks that move them in a circular motion as they spray water on the crops and lateral move irrigation. This type of irrigation also uses sprinklers, which move manually or mechanically across the field and then reconnected to a hose. While lateral move irrigation requires more effort, farmers may find it more economical (Amanda, 2003). The different types of irrigation systems are indicated in Figure 1.

Fig.1. Types of irrigation systems

The suitability of the various irrigation methods depends mainly on the following factors: natural conditions, type of crop, type of technology, previous experience with irrigation, required labour inputs, costs and benefits (Table 1).

Table.1. Factors considered in selecting irrigation methods (NEH, 1997).

No	Factors			Methods		
				Flood	Drip	Sprinkler
1.	Physical condition	Soil type		Clay	Sandy/clay	Sandy/ clay
		Slope		Gentle	Gentle/steep	Gentle/ steep
		Climate		Moderate T^o	-	Less wind
		Water availability		Need more	Less	Less
		Water quality	With sediment	Good	Not good	Not good
			dissolve salt	Not good	Good	Not good
2.	Types of crop			High/low	High	High
3.	Types of technology			Traditional/modern	Modern	Modern
4.	Required labour			More	Less	Less
5.	Cost and benefits			Small/large investment	Large investment	Large investment

As shown in Table 2.2. Surface irrigation is normally used when conditions are favorable: mild and regular slopes, soil type with medium to low infiltration rate, and a sufficient supply of surface or groundwater and need high labour input for construction, maintenance and operation. In the case of steep or irregular slopes, soils with a very high infiltration rate or scarcity of water, sprinkler and drip irrigation may be more appropriate. When introducing sprinkler and drip irrigation it must be ensured that the equipment can be maintained.

2.4. Irrigation institutions, policy and strategies of Ethiopia

Ministry of Water Resources (MoWR) is charged with aspects of water sector policy, planning, water resources regulation, development and use, and implementation of medium and large-scale irrigation. It also has the responsibility of building the capacity of regions regarding water resource development, and preparation of plans for the proper utilization of water resources. It coordinates projects that involve more than one region, or those that involve international procurement. The MoWR will render the implementation of the project by establishing a project coordination office (PCU). Under the economic policy of the government, the private sector can play a pivotal role in the development of irrigated agriculture. The international and local None Governmental Organizations also play a significant role in study, design and development of small-scale irrigation schemes in different regions.

According to the Ethiopian Water Resources Management Policy, the overall objective of irrigation policy is to develop huge irrigated agriculture potential for the production of food crops and raw materials needed for agro industries. The irrigation policy encourages irrigation activities to be implemented on an efficient and sustainable basis and without degrading the fertility of the production fields and water resources base. The specific objectives are:-

- Development and enhancement of small scale irrigated agriculture and grazing lands for food self-sufficiency at the household level.

- Development and enhancement of small-, medium- and large - scale irrigated agriculture for food security and food self – sufficiency at national level including export earnings and to satisfy local agro-industrial demands.
- Promotion of irrigation study, planning and implementation on economically viable, socially equitable, technically efficient, environmentally sound basis as well as development of sustainable, productive and affordable irrigation farms.
- Promotion of water use efficiency, control of wastage, protection of irrigation structures and appropriate drainage systems.
- Ensuring that small-, medium- and large-scale irrigation potential projects are studied and designed to a stage ready for immediate implementation by private and/or the government at any time

A report by Nile Basin Development Challenge -NBDC (2011) stated that in Ethiopia several important policies have been developed and adopted. However, five major challenges are quite often mentioned with respect to policy implementation. Those are:

- In many instances, policy implementation guidelines, laws and regulations are lacking.
- There is a general lack of policy implementation capacity at all levels.
- There is a general lack of proper policy implementation, monitoring and evaluation.
- Policies
- are made without adequate assessment and drawing lessons of existing/old policies (strategies).
- Policy coordination and integration (across sectors) is a challenge.

There are some main problems that are witnessed in the policy formulation and analysis. Some of these problems and shortcomings relate to:

- Less consideration given to taking evidences form grassroots and (through development performance evaluations).
- A general lack of adequate and up-to-date database for policy formulation.

- Lack of adequate analytical skill, models and knowledge.
- The absence of informed debate among the various stakeholders to feed into policy formulation and planning.
- Weak networking between the different stakeholders in policy formulation and implementation.

According MoWR irrigation development strategy is one of the sub-sectors dealt in the water sector strategy. The principal objective of the irrigation development strategy is to exploit the agricultural production potential of the country to achieve food self-sufficiency at the national level, including export earnings, and to satisfy the raw material demand of local industries, but without degrading the fertility and productivity of country's land and water resources base.

More specific objectives of the strategy are:

- Expand irrigated agriculture
- Improve irrigation water-use efficiency and thus the agricultural production efficiency
- Develop irrigation systems that are technically and financially sustainable
- Address water logging problems in irrigated area

2.5 GIS for water resource management

The application of Geographic Information System (GIS) has become popular in water resources management due to its dynamic nature to incorporate data and display results. GIS techniques are more time and cost efficient than the conventional field techniques and can be used to formulate a management plan much more efficiently and link land cover data to topographic data and to other information concerning processes and properties related to geographic location (Eduardo et al., 2012).

GIS science has played a major role in the development of distributed hydrologic models and in improving our understanding of the spatial aspects of the distribution and movement of water in landscapes. It has also greatly influenced the study of the impact of land use on water resources (John et al., 2000). GIS is also playing an important role in mapping water quality and quantity for assessment and monitoring purposes, it has been a fast developing technology in spatial information processing. Users can enter, store, retrieve, process and display spatial information from different data sources (Mahmoud, 2010).

GIS can provide irrigation scheduling is the farmers decision process relative to ‘‘when’’ to irrigate and ‘‘how much’’ water to apply at each irrigation event. It requires knowledge of crop water requirements and yield responses to water, the constraints specific to the irrigation method and respective on-farm delivery systems, the limitations of the water supply system relative to the delivery schedules applied, and the financial and economic implications of the irrigation practice (Smith et al., 1996 in Fortes et al., 2005). Small-scale irrigation (SSI) usually indicates irrigation practices on small plots, in which small farmers have the major controlling influence, and using a level of technology which the farmers can effectively operate and maintain (Adugna, 2014).

GIS functionality can play a major role in spatial decision making. Considerable effort is involved in information collection for the suitability analysis for irrigation farming. This information should present both opportunities and constraints for the decision maker (Ghafari, et, al., 2000).GIS have the ability to perform numerous tasks utilizing both spatial and attribute data stored in it. It has the ability to integrate variety of geographic technologies like GPS, Remote Sensing etc. The ultimate aim of GIS is to provide support for spatial decisions making process (Foote and Lynch1996). In multi-criteria evaluation any data layers are to be handled in order to arrive at the suitability, which can be achieved conveniently using GIS.

CHAPTER THREE

3. Data source and methodology

3.1 Study area and site characteristics

Gudo Beret is one of the 33 kebeles (smallest administrative unit) of Basona Worena (district). It is located at the eastern edge of the Ethiopian highlands in the North Shewa zone lying between 574444m - 572247m Northern latitude and 1083370m.-1080218 m Eastern longitude (Figure 2). Administratively, the kebele is located in the Basona Woreda (district) of the Amhara region. Elevation ranges from 2500 to 4000 meter above sea level. Gudo Beret has two rainy seasons (short and long or belg and kiremt seasons). The long season occurs between June and September whereas the short rainy season lies between February and April. There are 1429 households (1093 male and 336 female). Total population is 6715 (3680 male and 3035 females) (Gudo Beret kebele office, 2016). This study is linked to the Africa RISING (AR) project which aims to promote sustainable intensification through appropriate use of technologies and inputs.

Gudo Beret farms represent a highly intensified farming system. The dominant farming system of the kebele is mixed-crop livestock production. Cultivated areas and woodlots (dominated by eucalyptus) are the dominant land use/cover types. Main food and income crops are: Faba bean, irish potatoes, wheat and barley. During the long rains, farmers grow wheat, faba bean, chick pea, teff, barley, irish potatoes, field pea, lentils, linseed, garlic, cabbage, beet root and onions. Barley is the major crop during the short rains which dominates the upper part of the site. Eucalyptuses (Eucalyptus globulus) are the major tree species in the area. Juniper (Juniperus procera) in the highlands and Guassa grass (Festuca spp.) in the more extreme highlands areas are also common tree and grass species, respectively. Irish potatoes, vegetables and fruits were normally grown under irrigation.

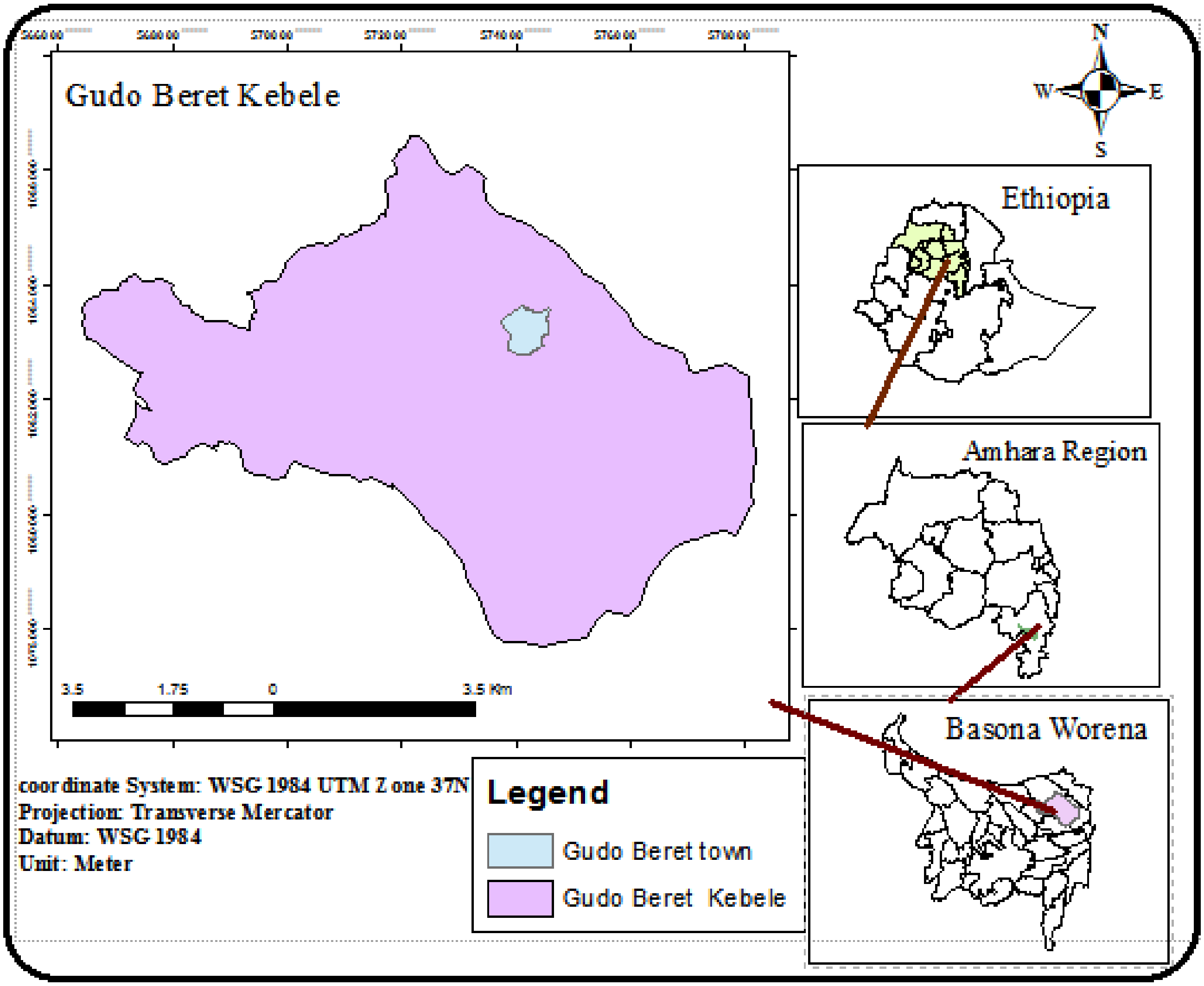


Figure.2 Location map of the study area

The main livestock species in Gudo Beret include: cows, oxen, sheep, donkey and chicken. Crop residues were the main source of fodder for livestock for majority of the farmers, being utilized for more than six months annually. Some farmers mix hay with crop residues and local beer products "Atela" in order to improve the nutritional value and feed to small ruminants and cattle. "Atela" is a local brew by-product. The local brew is made from barley and Rhamnus prinoides shrub leaves. Other fodder sources include grasses, tree fodder and weeds from crop fields. There is low diversity of tree fodder, with mainly Chamaecytisus palmensis (tree lucerne) being the most commonly utilized fodder tree species.

Eucalyptus plantation/woodlots are dominant trees that are grown by farmers' with fields mainly for income generation from selling of the poles. It has become number one important cash source for the entire communities in the 'woreda'. Highland fruit, particularly Apple is expanding at high rate in the Gudo Beret kebele due to agro-ecological suitability and high market value. Root crops such as potato are also commonly cultivated by large number of farmers. Off-farm employment and traditional cloths making are also other source of livelihood for few farms. As shortage of land is becoming a prominent problem, weaving is becoming a means of livelihood for few small landholders and landless households.

Gudo Beret is dominated by higher elevation and thus can be categorized as highland area. Elevation ranges between 2332 and 3490 meters above sea level (Figure 3).

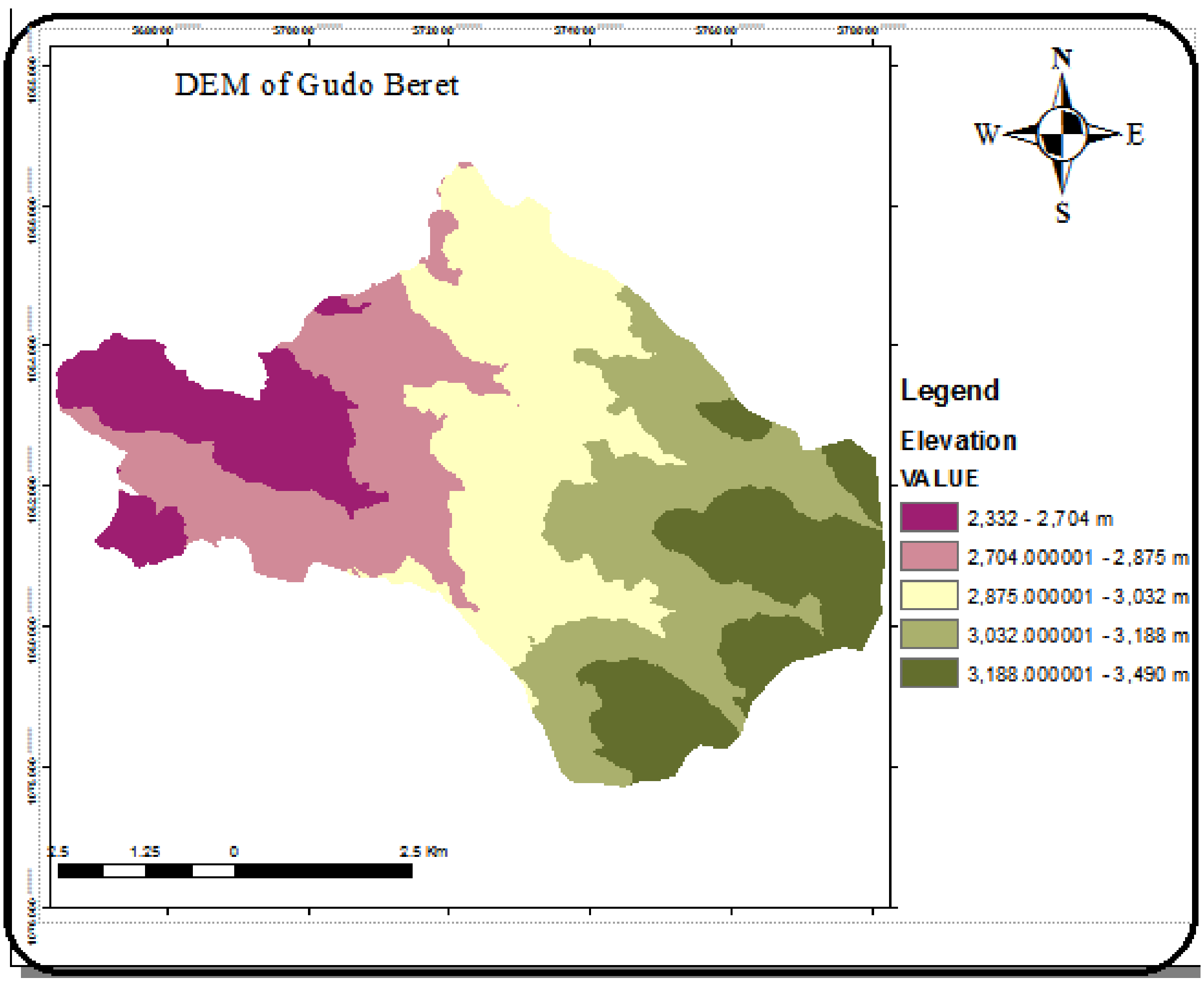


Figure.3. DEM of the study area

Temperature in the study area generally ranges from as low as – 5 degree Celsius during autumn/winter to over 25 degree Celsius during spring/summer seasons (ILRI2014/2015). The area receives short and long rains the dominant being the long rains of summer. During the summer season (June-September) the area gets rainfall of up to 308.5 mm while during the short rain period (February-April) the amount of rainfall received can be as low as 13.5 mm. Based on data acquired from (ILRI, 2014/2015) mm.

Table.2 means rainfall and temperature of Gudo Beret kebele

Month	Mean rainfall (mm)	Mean temperature (^oC)
January	13.5	12.1
February	29.5	13.6
March	66.5	12.4
April	64.5	13.4
May	55.5	13
Jun	75.5	14
July	308.5	11
August	257	12
September	119	9.9
October	35.5	9.5
November	18.5	9.3
December	75	10

There are three major types of soil Eutric Leptosols, Eutric Regosols and Eutric Vertisols. Gudo Beret has patches of government forest areas mainly comprising of Eucalyptus globulus, Eucalyptus camaldulensis and Cupressus lusitanica. Initially, the government forest was called the ‘firewood project’, which was planted during Emperor Menelik II’s rule-under a program that aimed at improving household energy/ firewood (Kuria, et al., 2014). However, it is currently called the Amhara Region Forest Enterprise. The plantations serve the wood product processing firms in Debre Birhan and neighboring towns. Although the communities are not allowed to cut trees from the government forest, they are allowed to collect firewood and eucalyptus leaves which they use and some sell the surplus for income. There is a community forest at the upper end of the kebele in Gina sub-kebele. It is owned by 20 farmers who planted both Eucalyptus globulus and Eucalyptus camaldulensis in 2000. They plan to sell the trees once mature and share the benefits equally. Other forests existing in the kebele were mainly woodlots owned by individual farmers.

3.2.Data collection and analysis methodology

3.2.1 Selecting study irrigation schemes

Before site selection, a preliminary field visit was conducted in November 2015. The main goal of the field trip was to have an overall idea of the study site, discuss with stakeholders such as Bureau of Agriculture staff, District and Kebele level administration and local communities. During the field visit, irrigation schemes were visited. Among those, three were selected to be included in this study. These three irrigation schemes are (Figure 5): Mush irrigation scheme is located at about 26 km from Debre Birhan city, Feleku is at 31 km and Weynabchu is at 29 km. In all irrigation cases irrigation practices traditionally started from the imperial regime of the country. But, Mush irrigation scheme communities have been organized as Mush irrigation water user cooperatives (IWUC) under the proclamation No. 40/1999 articles 6/6 in 2006 and registered by cooperatives promotion Bureaus of Amhara National Regional state. Currently Mush IWUC has 74 males and 32 females with a total of 106 members, Feleku has 38 males and 16 females with total of 54 members and Weynabchu has 30 males and 12 females with a total of 42 household members. Under Mush scheme 41.5 ha is under irrigation while at Feleku and Weynabchu, the irrigation area covers about 24.4 and 18.9 ha, respectively. The total land cultivated by irrigation under those three schemes 84.8 ha.

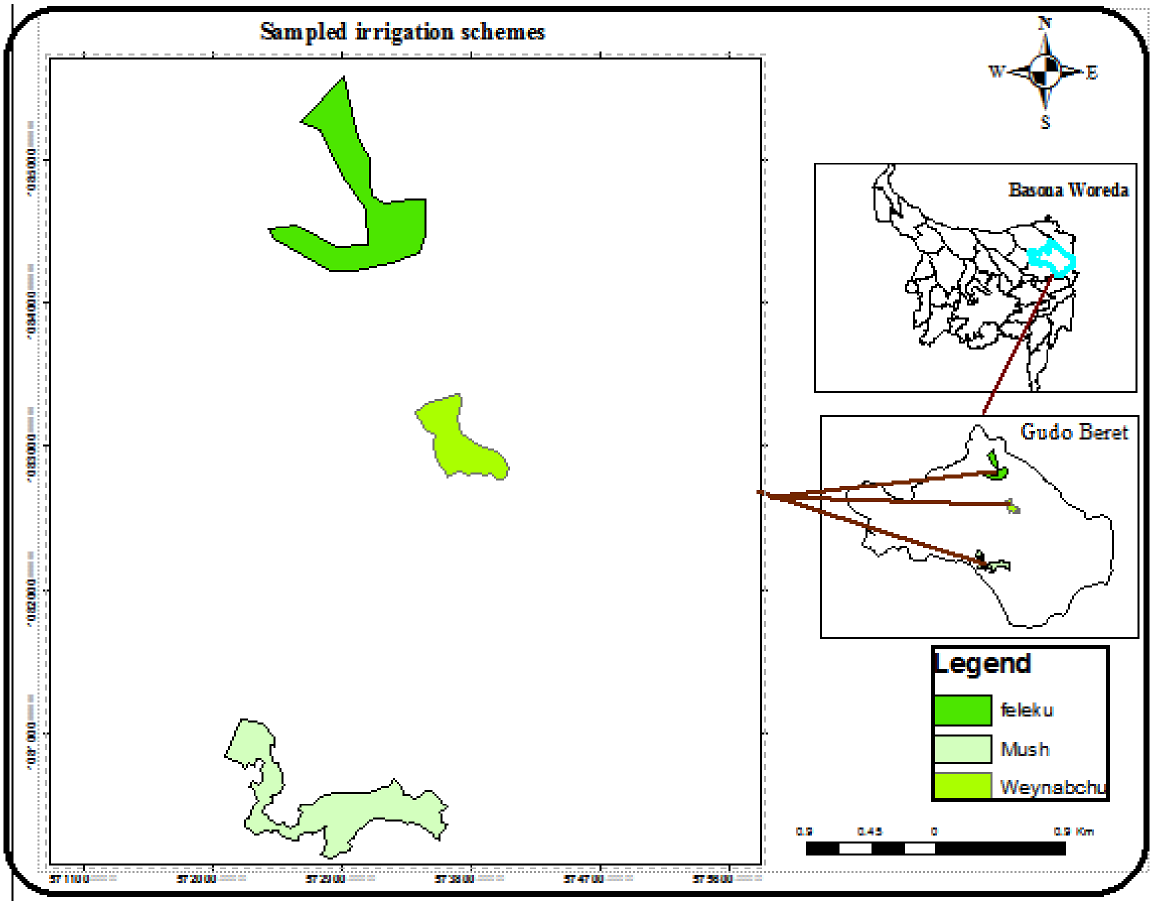


Figure.4 boundary of sample irrigation scheme

3.2.2 Data sources

In order to achieve the objectives of the study primary and secondary data were used. Data's were based on field visits, surveys, questionnaire, interview and focus group discussion. Additional primary data including satellite image, soil data, climate data and elevation data (DEM) were obtained from the International Livestock Research Institution (ILRI) and Ministky, of water resource. Secondary data were mainly required for assessing available water resource used for irrigation and historical background of irrigation in the study area. Moreover, documentary data were found in the Kebele agricultural office and water user cooperative (WUC). Additional supportive data were acquired from research reports and books.

Survey data collection method was mainly employed to obtain empirical data from the study area. This includes cropping pattern, land use and land cover, GPS points, irrigation water conveyance system and physical condition of irrigation schemes.

Questionnaire tool was designed to acquire primary data from respondents which were selected from the three irrigation schemes. Specially, it was focused on water use and management, constraints facing small scale irrigation cropping pattern, policy and institution by law, technology utility, nutrition and gender issues and irrigation farming experience.

Interview was employed to obtain data required from the key informant including development agents who were working in kebele agricultural office and water user cooperative committee members. Moreover, this method was also employed when further clarification were required from some informant

Focus group discussion (FGD) is useful to gather data based on participatory approach. It allows participants to agree and disagree with each other and helps to understand group's thinking about constraint SSI, irrigation policy, institutions by laws, irrigation farming experience and water management practices. It can also help document challenges within the community and suggest possible solutions to address those challenges.

3.2.3 Sampling design

Important factors to be considered in selection of sample schemes in the study area were recognized during the preliminary survey. The most important factors were accessibility, source of irrigation water (i.e. river and spring) and structure of user's and management (i.e. organized within WUC and without). Based on the data obtained from kebele agricultural office, three schemes from different water supply categories were selected. In order to select farmers for interview, it was necessary to know the total number of water users in each Kebele (under the respective schemes). Accordingly, the total number of water users was gathered from kebele agricultural office. The total number of irrigation user’s was 106, 54 and 42 in Mush, Weynabchu and Feleku schemes, respectively. The final sample population was selected based on stratified random sampling

The stratification was made based on the relative distance of farmer’s irrigation plot from the main canal. Accordingly, a total of 100 respondents (49.5% of the population) proportionally based on their total number 53, 26 and 21 from Mush, Feleku and Weynabchu respectively were identified for questionnaire survey. Out of the total 100 households selected for questionnaire interview, 30 were females. For FGD, a total of 18 people participated out of which 15 were elderly man while 3 were female.

3.3 Data analysis

The data were analyzed using qualitative and quantitative methods of data analysis. All non-quantitative data and field observation were analyzed qualitatively. The various quantitative data obtained from both primary and secondary data source were analyzed by various statistical methods such as descriptive statistics and regression. The analyses results were then presented in the form of tables, charts, graphs and maps.

The data were gathered from field visit, satellite image, topographic map, interview, geographic coordinates of place was collected by using (Ground Positioning System (GPS)). The spatial data were stored and analyzed using GIS 10.1. The various tools in ArcGIS were used to generate stream network and a quantitative understanding of evapotranspiration. The different between precipitation and evapotranspiration is the water available for direct human use and management. Moreover evaporation has a significant influence on the yield of water supply. Therefore evaporation control is a subject of major importance in conserving the water supplied to the rivers.

Thornthwaite (1948) suggested an empirical formula for estimating potential evapotranspiration using the mean temperature and humidity. He developed the following equation. $PEm=16Nm\ (10Tm/I)^{a}$ Where; PEm: monthly evapotranspiration, monthly Nm: monthly factor of day light, Tm: the monthly mean temperature in ^{o}C, I: annual humidity, a= 0.000000675 I3 -0.0000771 I2 +0.01792 I+ 0.49239 and water balance equation (P-E) (Majumand, 2002)

Remote Sensing data analysis software such as ERDAS IMAGINE used to generate land use/land cover map of the study area. In this study land use /cover map was developed using 2014 satellite images PALADIS 0.5m x 0.5m resolution. Supervised classification with ground verification was used to derive the final land use/land cover maps.

To map irrigable area need to the suitable area for irrigation, land suitability for irrigation is determined by main consideration; soil depth, soil type, slope and land use and also 70 meter buffer zone from urban (should far from round urban settlement by 70 meter) (Table 2). Land slope and its uniformity are two of the most important topographical factors influencing land evaluation for irrigation suitability. Slope is clearly an important agro-ecological parameter. It has direct implication on cultivation; steeper slope are more difficult to cultivate than gentler slopes. According to FAO (1985) guidelines, slopes above 30% should not be cultivated and slope less than 12 % is suitable for irrigation farming. In the study area slope is range from 0 to 164 %. The slope map was derived from the DEM layer using the spatial analysis in ArcGIS, which clearly shows slope distribution and suitability. Soil depth is one of the most important aspects which should be investigated in terms of its suitability for irrigation. It does not only influence the root development and soil water reservoir, but also the degree of drainage past the root zone. Over-irrigation usually takes place and this water must be able to drain away without any problems. While a depth of 150cm is ideal in well drained friable soil, experience has shown that if the soil depth is more than 90cm it may be classified as irrigable (Meron, 2007). In the study soil depth is ranges from 66-155cm. the influence of factors calculated by using the analytic hierarchy process (AHP).

Table 3.table of Suitability class (FAO, 1983)

Order	Class	Description
Suitable (S)	S1 (Highly suitable)	Land having no, or insignificant limitations for a given type of use
	S2 (Moderately suitable)	Land having minor limitations for a given type of use
	S3 (Marginally suitable)	Land having moderate limitations for a given type of use
Not suitable (N)	N1 (Currently not suitable	Land having severe limitations that preclude for a given type of use, but can be improved by specific management
	N2 (Permanently not suitable)	Land that have so severe limitations that are very difficult to be overcome

Data were gathered based on FGD, observation, interview with elders and key informants (DAs), and from secondary source. The qualitative data were analyzed using qualitative method such as categorical while quantitative data's were analyzed using quantitative methods.

CHAPTER FOUR

4. Results and Discussion

4.1 Analyzing water resources, land use/land cover and irrigable lands of the study area

4.1.1 Available surface water resources

Mehal Amba, Mush, Boro Ager, Weynabch and Feleko are the five water sources that exist in the study area (Figure 6) Feleko River is used for irrigation purpose while the others become dry during the Bega (dry) season when irrigation water is needed. There are also nine springs that serve as source of water in the area. They are Ahaya, Beteskian Amba, Chigigni Tabiya, Salasfa, shinet, shola, Weldeab Ager and Weynabch (Figure 6) out of all springs Engichit, Ahaya, Shinet and Weynabchu are used for irrigation while the others provide clean drinking water for the local communities.

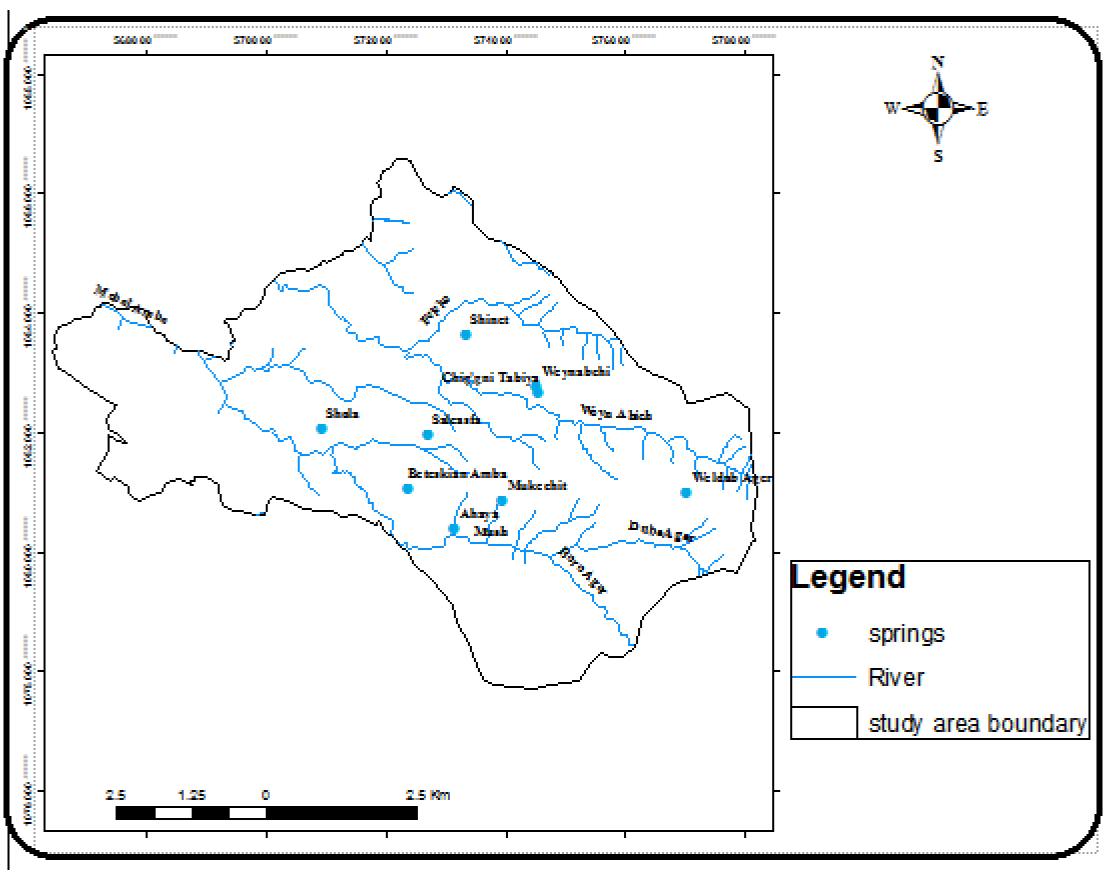


Figure.5 Spatial distribution of water resources in the study area

Participants indicated during FGD discussion that the rivers and springs drying up because of Eucalyptus trees planted around them, climate change, population pressure, land use/cover changes and landslide. Moreover, evaporation has a significant influence on the yield of water supply. Therefore evaporation control is a subject of major importance in conserving the water supplied to the rivers. Distribution of rainfall and temperature in the study area is indicated in Figures.

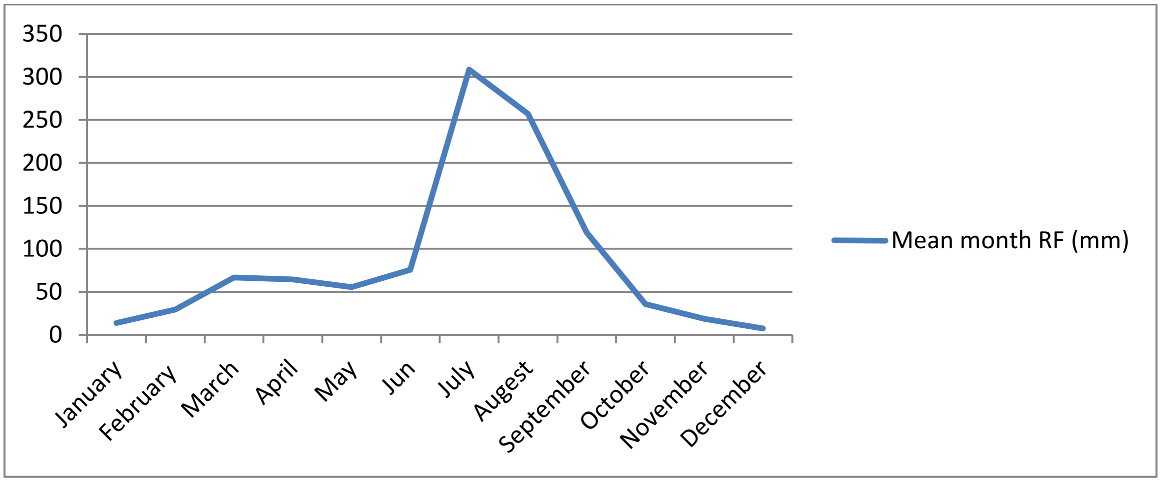


Figure 6.Distribution of mean monthly rainfall in the study area (ILRI, 2014/2015)

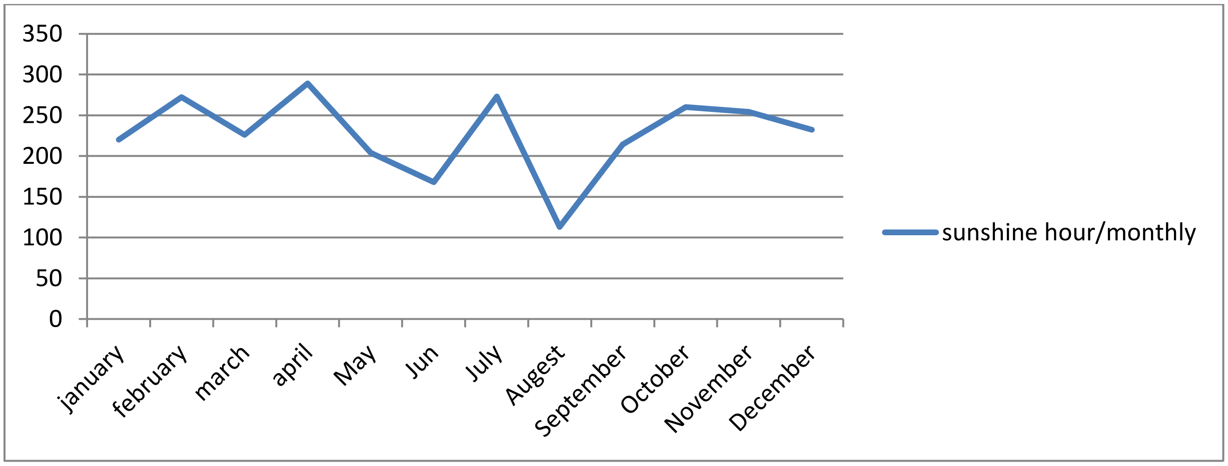


Figure 7 Distribution of mean monthly sunshine hour in the study area (ILRI, 2014/2015)

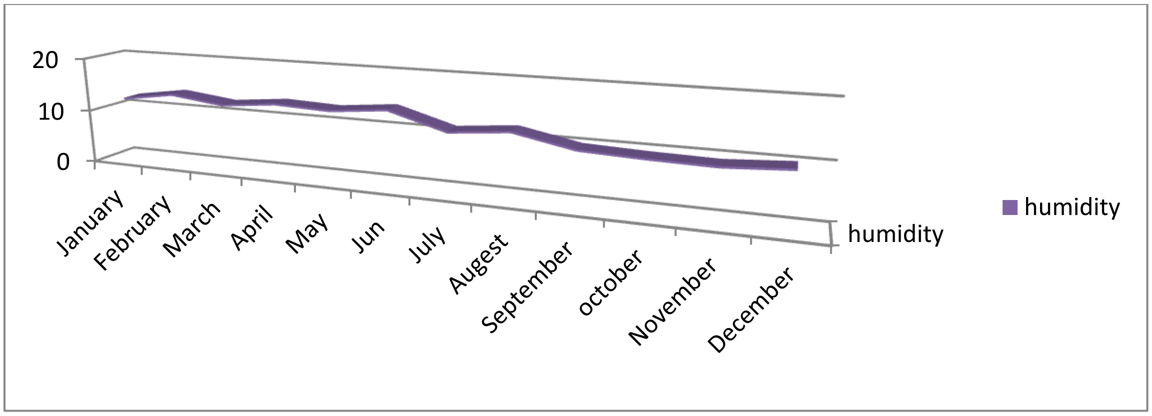


Figure 8.Distribution of mean monthly humidity in the study area (ILRI, 2014/2015)

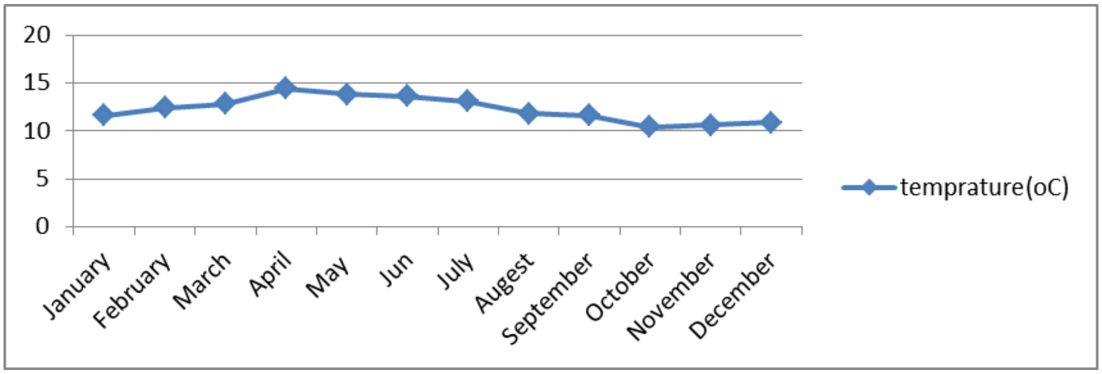


Figure.9 Distribution of mean temperature in the study area (ILRI, 2014/2015)

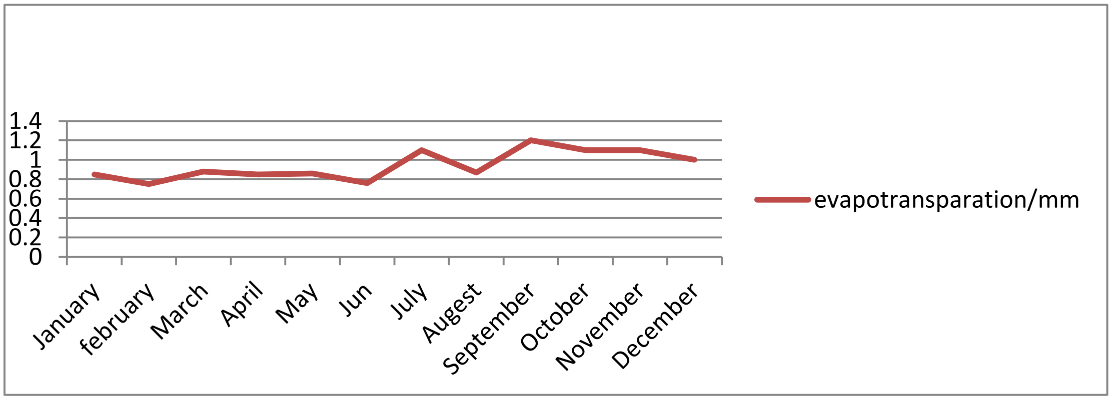


Figure.10 Distribution of evapotranspiration in the study area (ILRI, 2014/2015)

The study area received mean month rainfall that ranges from 7.5 mm to 308.5 mm. The months of July up to September received high amount of rainfall. The rest of the months received low rainfall. Due to low temperature the expected evapotranspiration is low. Hence, the surface hydrological components of study area were the only governing factors. The annual water balance is 52.74 mm3/ year. However, this amount includes the water loss by infiltration and runoff.

4.1.2. The current land use/land covers of the study area

Satellite image classification results show that there are six major land use types. These include bare land, built up area, farm land, forest, grass land and water bodies (Figure 12).

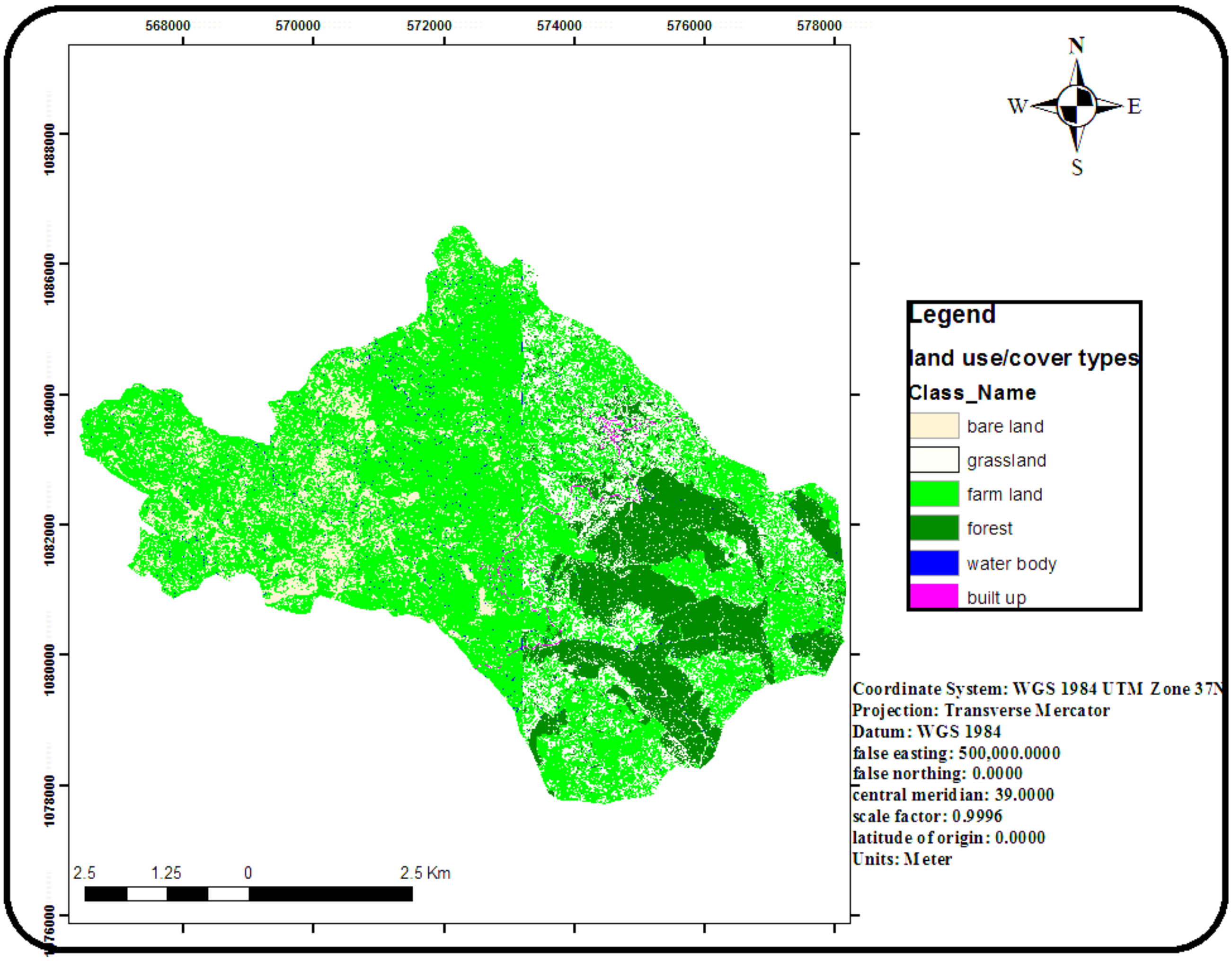


Figure.11 Spatial distribution of land use/cover types of the study areas

Based on the land use/cover classification cultivated land, forest land, grass land, bare land, built up area and water bodies constitutes 3045, 850, 616, 434, 16 and 26 ha, respectively. Generally, the majority of the study area is cultivated land constituting 60 % followed by forest land 17% and grassland 12%

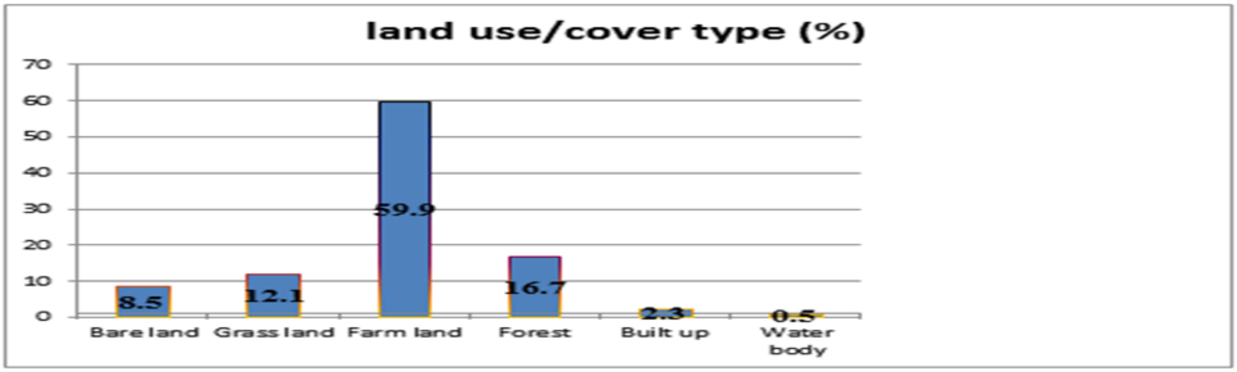


Figure.12 areal coverage of land use/cover classes in percent

4.1.3 Irrigable areas

Irrigation efficiency was determined based on the consideration: soil type, slope, soil depth and land use/cover types of the area.

The major soil types found in study area are Leptosols, Regosols and Vertisols. Vetisols has very low EC and N low availability of phosphorous medium total organic carbon content; high $CaCo_3$; very high cation exchange capacity (CEC) with moderately alkaline PH. Regosols has a very low EC and N total; low CEC and total organic carbon content; high $CaCo_3$ and phosphorous; slight acidic PH. Leptosols has high CEC and organic carbon content, higher $CaCo_3$ and slight alkalinity PH.

Table.4 Suitability of major soil types for irrigation farming.

No	Major soil types	Suitability
1	Leptosols	S1
2	Vertisols	S2
3	Regosols	S3

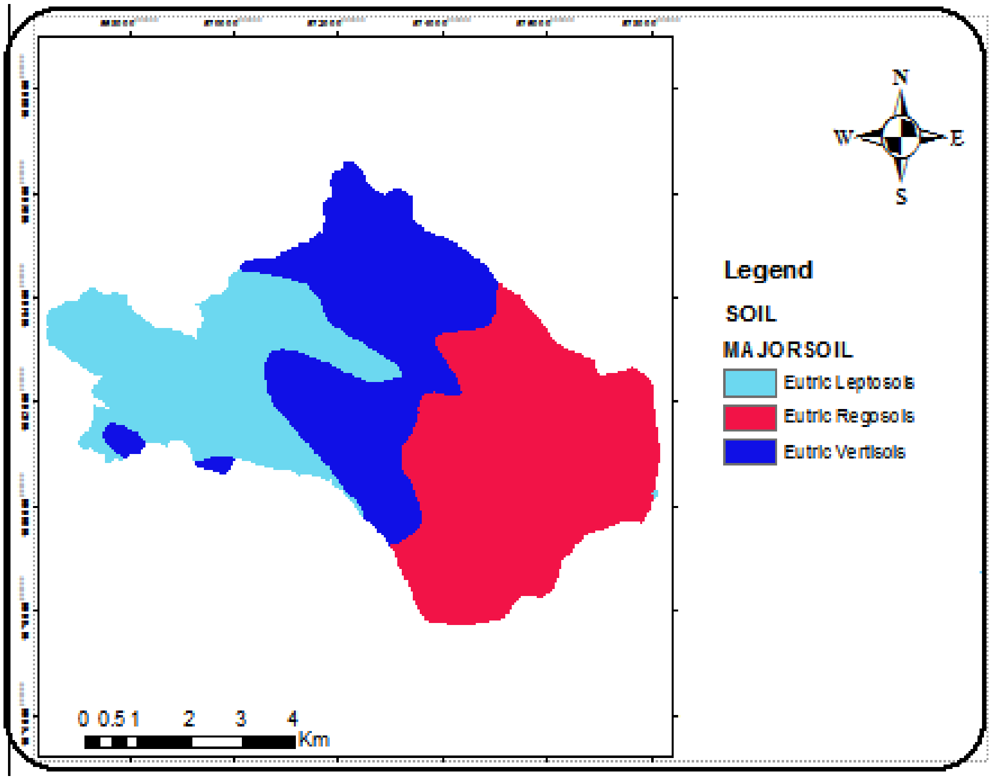


Fig.13 major Soil type map of study area

The length of the irrigation run, crop adaptability, erosion control practices, cultural practices, and irrigation method may be influenced by the land gradient. The slope of the study classified into three classes as 12% (suitable), 1215% (less suitable) and > 15% (unsuitable) using ArcGIS facility (Table 3 and Figure 14).

Table.5 Slope suitability for irrigation in the study area

No	Classes	Raster value	Suitability
1	Flat	0-12 %	S1
2	Moderate	12.1-15%	S2
3	Steep	15.1-164%	N2

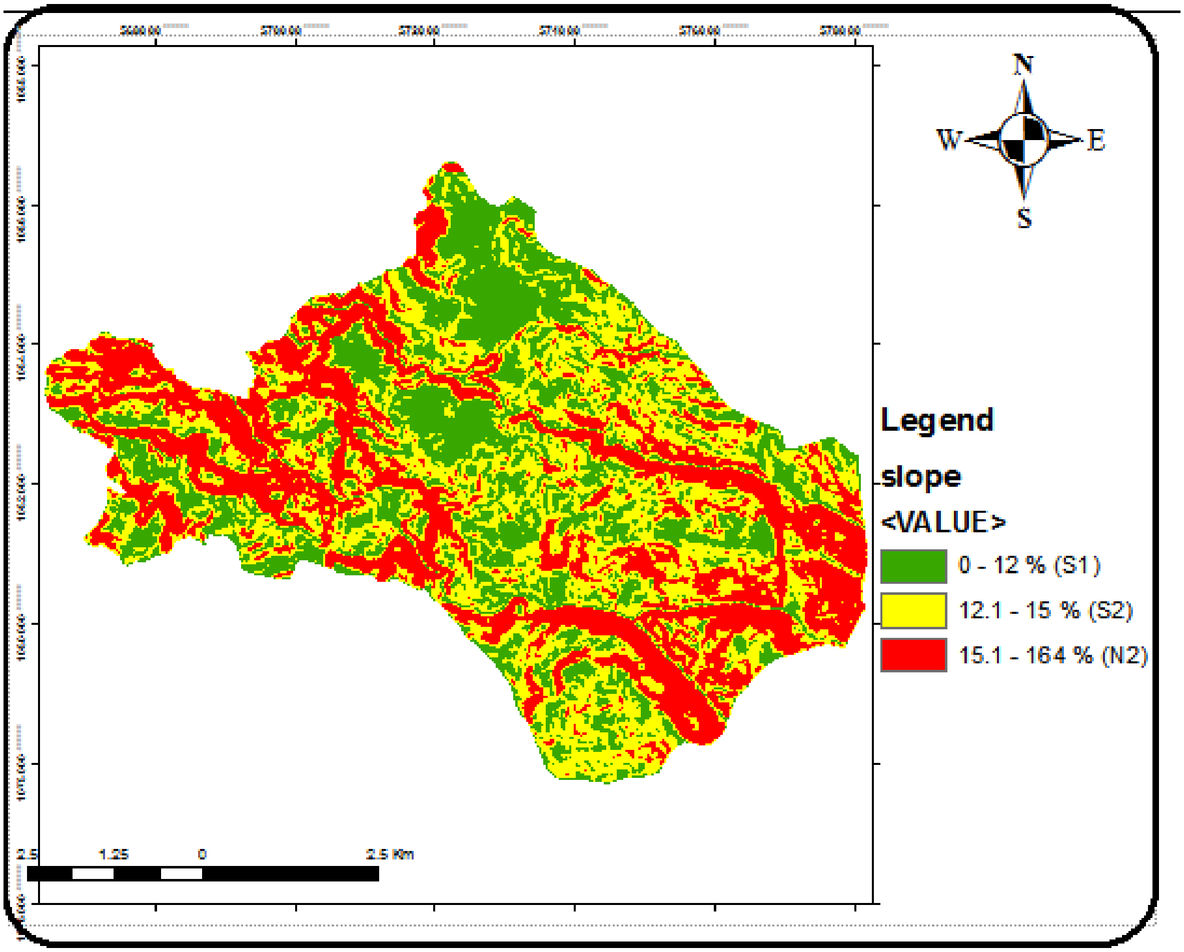


Figure.14 The spatial distribution of terrain slope and its suitability for irrigation

Table.6 Soil depth suitability for irrigation in the study area

No	classes	Range (mm)	Suitability
1	Shallow	0-89	N
2	Medium	90-100	S2
3	Deep	101-155	S1

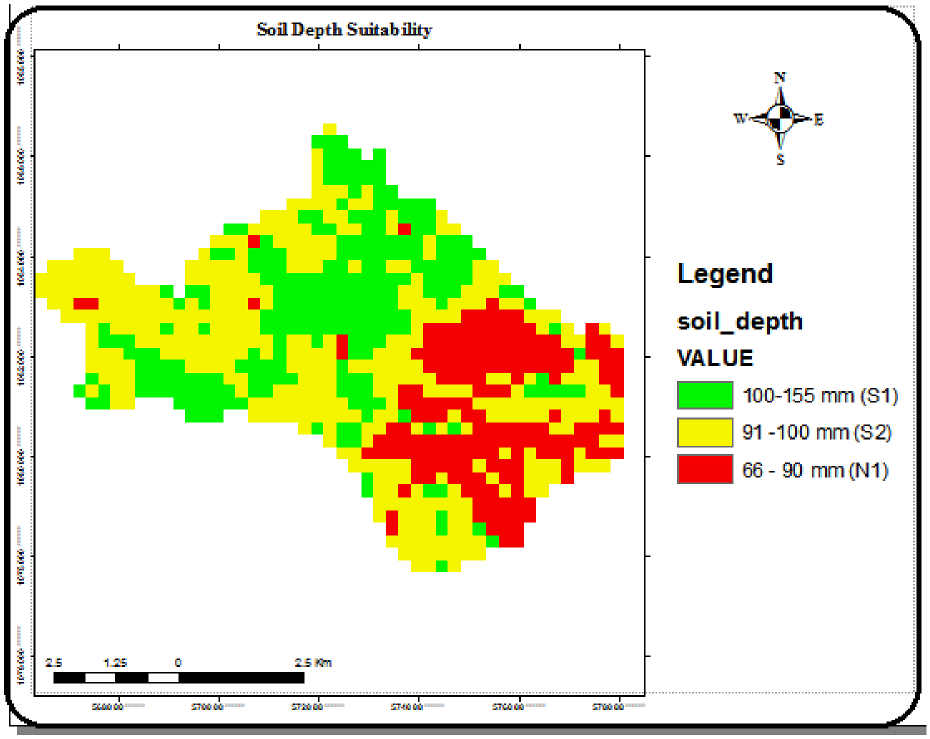


Figure.15 The distribution of soil depth suitability for irrigation

The six mentioned main land use/cover classes Figure (12) are used in rating the land cover for suitable and not suitable orders based on the most limiting factors. This limiting factor includes lands that are already dense forest, bare land, water body and urban areas. For each suitable order there are two classes that reflect the limitation that restrict the suitability of that land mapping unit for the irrigation purpose due to its environmental, social or economic cost, unless some important measures are taken. These two classes are farm land highly suitable (S1) and grass land moderately suitable (S2).

Table.7 Suitability of land use types for irrigation

No	Classes	Suitability
1	Cultivated land	S1
2	Grass land	S2
3	Forest	N1
4	Built up	N1
5	Bare land	N2
6	Water body	N2

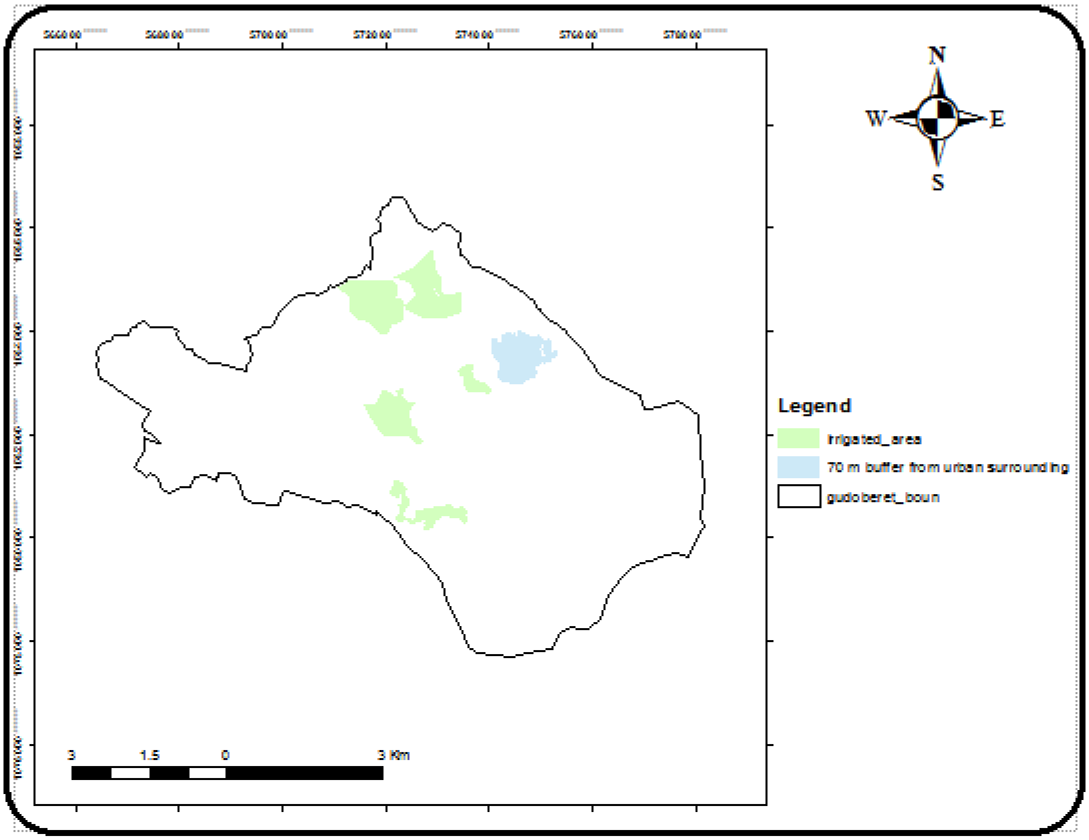


Figure.16 Distribution of irrigated land and buffer from urban settlement

The slope, soil depth, and land cover data layers are used for the GIS analysis. Each layer was categorized in to different class of suitability (suitable, less suitable, and not suitable) using different criteria considering land qualities required by surface irrigation method from the slope, soil, and land cover aspect. After checking and correcting each layers for their accuracy and reliability the overlaying analysis procedure were carried out using the GIS environment (weighted overlay). The three layers slope, soil depth and land cover overlaid in order to find the suitable land for irrigation (fig.4.1.4, 4.1.5 and 4.1.6). The slope layer was taken to be the base map for overlaying due to its being the most limiting factor in practicing surface irrigation agriculture. Then, suitability of raster layer was converted to the vector layer to make overlap with buffer from urban settlement, existing irrigated area and water resource layers (fig.4.1.8). The implementation of the GIS technique reduces the time and cost of the general evaluation process by narrowing the investigation to areas that are already evaluated by the most limiting factor for irrigation agriculture practices.

Table.8 Weight matrix index of criteria's to select suitable area for irrigation.

No	Theme	Weight (fraction)	Weight (decimal)	% influence	% of contribution
1	Soil type	1	1	0.49	49
2	Slope	1/3	0.33	0.29	29
3	Soil depth	1/5	0.20	0.15	15
4	Land use/cover	1/7	0.14	0.07	7

Based on the analysis, 1481 ha, which is 40% of total area of farm land and grassland also 29% of total of study area was irrigable land. 789 ha (21%) of farm land and grassland and 16% of study area were moderately irrigable based on physical factors. While the rest portions were can not be irrigate (fig.19). However, this suitable area can be further up graded to suitable classes and dawn graded to not suitable classes by carrying out evaluation from socio economic parameters in addition to this physical resource evaluation only.

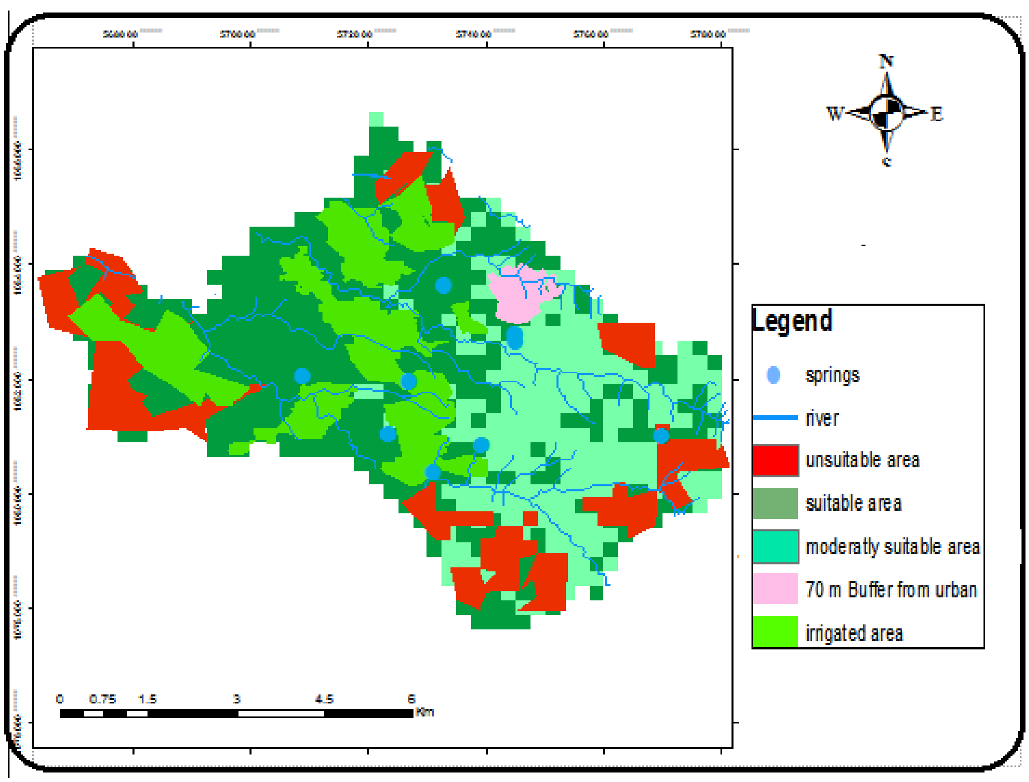


Figure17. Distribution of irrigable area in the study area

CHAPTER FIVE

5. Technology, water management and constraints

The selected schemes were Mush, Feleku and Weynabchu schemes. These irrigation schemes were mainly used as a source of water springs and river such as, Engichit, Ahaya, Shinet and Weynabchu springs and Feleku River.

5.1. General profile of respondents

5.1.1 Age and sex profile

Data obtained from 100 respondent returns revealed that the age of respondents' ranges between 35-65 years. The majority of the respondents were found between 41 and 55 (Table 9). This group accounts about 86% of the total respondents.

Table.9 Distribution of respondents of irrigation schemes by age and sex

Age	Mush			Feleku			Weynabchu			Total			% of the total
	M	F	T	M	F	T	M	F	T	M	F	T	
36-40	3	-	3	1	-	1	-	2	2	4	2	6	6%
41-45	5	6	11	7	2	9	8	4	12	20	12	32	32%
46-50	10	8	18	5	5	10	6	-	6	21	13	34	34%
51-55	12	2	14	4	1	5	1	-	1	17	4	20	20%
56-60	5	-	5	1	-	1	-	-		6	-	6	6%
61-65	2	-	2	-	-	-	-	-	-	2	-	2	2%
Total	37	16	53	18	8	26	15	6	21	70	30	100	100

5.1.2 Educational background

The educational status of the respondents in the three selected schemes varied from illiterate to secondary educational level. As can be seen from the (table 10), 60% of the total respondents are illiterate, about 39% are primary and also 1% of respondent have secondary education levels. Education level can thus be considered as one of the major factor to use irrigation technologies appropriately and also affect water use efficiency.

Table.10. Educational background of respondent

Name of scheme	Illiterate	Primary		Secondary	Total
		first cycle (1-4)	Second cycle (5-8)		
Mush	25	19	8	1	53
Feleku	20	4	2	-	26
Weynabchu	15	6	-	-	21
Total	60	29	10	-	100
% of the total	60	29	10	1	100

5.1.3. Number of family members of sample households

The total numbers of family members of the 100 respondents are 484 from this about 213 or 44% are female and 59 or 12% are infant. According to table 9.41% of the total families are dependent or no productive. The number of productive age has influence on the production Participant families in irrigation practice are only 59% this can affect irrigation farming and production.

Table.11 Number of respondent families

No	Age	Sex (by No)					
		M	%	F	%	T	%
1	<5 year	24	8.8	35	16.4	59	12
2	6-14 year	71	26.2	55	25.8	126	26
3	15-65 year	173	63.84	112	52.5	285	59
4	>65 year	3	1.1	11	5.1	14	3
	Total	271	100	213	100	484	100

From the total number of respondent families 285 (59%) are under worker age (15-65) and the rest 12% of family members are below five years, 26% are between 6-14 and 3% are above 65. These shows about 41% of the total family members are dependent or not productive. The number of productive age on the family has influence on the production.

5.1.4. Religious status of respondents

Religion can affect the culture and practices of communities. In the study area orthodox religion is dominant and has long history with the society. All respondents are follower of orthodox Christianity**.** The numbers of working day are limited due to a number of religious holidays.

5.1.5. Average land holding size and farming status

According to the responses obtained from the sample respondent of water users, the size of total farmland per household showed a marked variation. In general, the average size of farmland varied from 0.25 ha to 1 ha in the selected households. The farmlands were broadly categorized in to rainfed and irrigated farmlands. As listed in table 10, the largest portion of the total farmland of the sample households of irrigation schemes was cultivated under the rainfed system, which covers about 70 % of the total farm land also the irrigated farmland category in the perspective schemes. This category also covers 30 % of the household's total farmland in the sampled irrigated schemes.

Table.12. Household farm size category and average size of land holding

Irrigation schemes	No of respondent	Total farmland	Farmland under				Average farmland per household		
			Rainfed		Irrigated		Rain fed	Irrigated	Total
			Ha	%	Ha	%	Ha	Ha	Ha
Mush	53	41.2 ha	27.8	67.4	13.4	32.6	0.52	0.25	0.77
Weynabchu	21	18.4 ha	10.6	57.6	7.8	42.4	0.5	0.37	0.87
Feleku	26	24.7 ha	13.5	54.7	11.2	45.3	0.52	0.43	0.95
Total	100	**84.3 ha**	51.9	61.5	32.4	38.5	0.51	0.32	0.84

5.1.6. Types of cropping pattern

Cropping pattern refers to the proportion of area under various crops; it indicated the yearly sequence and the spatial arrangements of crops. Cropping pattern of an area evolves based on physical and social environment and other factors of production in that area. Based on FGD, it was observed that wheat, barley, bean and pea were mostly cultivated under rainfed farming while potato, bean, white and red onion and lentil were produce under irrigated farming. According to the data obtained from respondents, the following criteria's applied for selection of crops in both the rainfed and irrigated farming condition.

- A good price in local market
- Based on farming experience
- For household consumption
- Less water requirement (for irrigated farming)

5.2. Constraints of small scale irrigation

Analysis results show that the constraints of small scale irrigation in the study area were inherently interlinked. Almost all respondents (92%) in the various irrigation schemes (Mush 85% while Feleku and Weyabchu 100%) indicated that seasonal irrigation water shortage is a critical problem to implement small-scale irrigation (Figure 19 and Table 11). They stated that water shortage is always anticipated during the dry season which affects the amount of area irrigated and the types of crops planted.

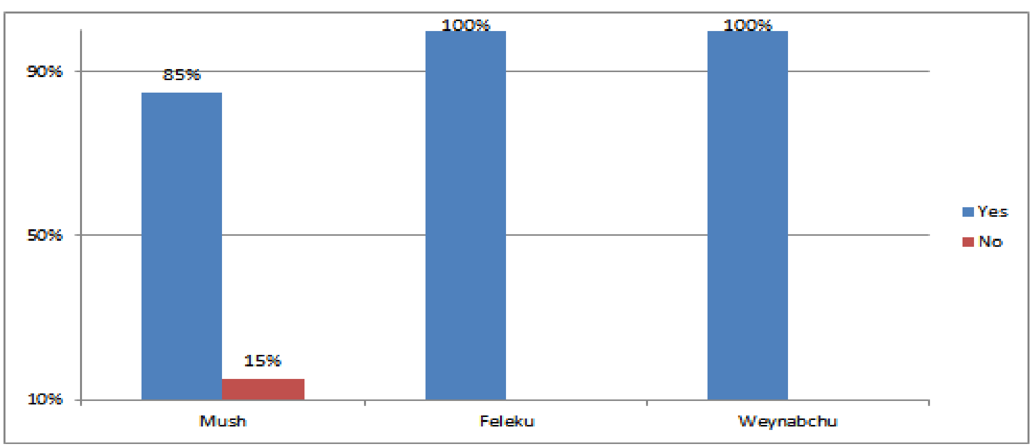


Figure 18.Seasonal water shortage in the study area

The respondents also identified some major causes that aggravated the seasonal water shortage. Although the causes vary across the different schemes, high temperature and inappropriate water use dominate across the schemes. In addition, cannel problem (89 %), high number of users (81 % of the respondents) and lack of water from the natural source (20 %) are considered to be major causes of irrigation water shortage in the study area.

Table.13 Causes of irrigation water shortage

Cause	Number of respondents				
	Feleku	Mush	Weyabchu	Total	%
Cannel problem	15	53	21	89	89
Sunny weather	26	53	21	100	100
High number of users	18	43	20	81	81
Inappropriate water usage	26	53	21	100	100
Lack of water from source	20	-	-	20	20
Total number of respondents	26	53	21	100	100

5.3 Water management and technologies

All respondents replied that they use flood irrigation method that they have adopted in the area (not because they think it is better). As a result there is high level of water wastage. In addition, the method is exposed to infiltration and evaporation that also causes water loss. Despite the fact that the majority of the respondents indicated the benefits of using improved technology to save water and their willingness to adopt, they also identified some constraints that undermine their ability to use those technologies.

Table.14 Technology usage of respondents

Technologies	Mush		Weynabchu		Feleku		Total	
	No	%	No	%	No	%	No	%
Fertilizer	53	100	21	100	26	100	100	100
Pesticide	15	28.3	-	-	5	19.2	20	20
Weedicide	-	-	-	-	-	-	-	-
Special seed	53	100	10	47.6	20	76.9	83	83

Mush irrigation scheme respondents have better technology utilization experience than the other two schemes. As mentioned on Table 12 the three schemes have good trend of fertilizer application on their farms. With regards to pesticides, 28.3 % and 19.2 % respondents in Mush and Feleku use to minimize yield losses. Improved seed are used in mush (100%), Weynabchu (47.6%) and Feleku (76.9%). However, herbicides are not applied by all respondents. Generally, from the total respondents 100% use fertilizer, 20% use pesticides and 83% use improved seeds (Figure 20). Generally, Utilization of technologies like pesticides, herbicides and improved seed is low. This problem is highly affecting productivity in the study area. According to the local farmers, the reason for low technology usage are due to lack of awareness, poor access to the technologies in the study area, high price of inputs and poor access to credit services to purchase inputs.

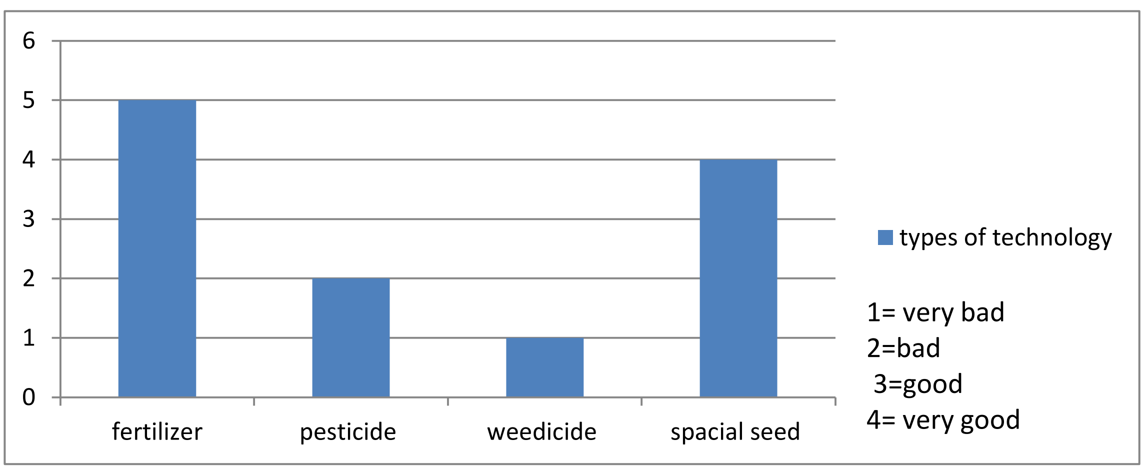


Figure 19.Availability of technologies (inputs) in the study area

Lack of long and short-term credit provision affects the production. The input for production like fertilizers, improved seeds and chemicals requires high financial input for purchasing (Berhanu, 2006). Moreover; lack of legal status for Water Users' cooperatives (WUC) can present a challenge to farmers. Unlike cooperatives, which are legal entities, WUC cannot access credit or hold bank accounts (Carter and Danert, 2006). That is why relatively better-off households benefited more because they have more land, labour and money to buy farm inputs, which allow them to exploit irrigation opportunities. Low capacity of farmers, lack of know-how in, and access to, the opportunities of irrigation technology; weak economic base of most farmers and the relatively high development costs involved in developing irrigation schemes are also the other key constraints (Mekuria 2003). In many parts of the country; the farmers are practicing irrigation without essential know-how on crop water need, water application method and irrigation interval Lack of knowledge of irrigation water management aspects has resulted in wastage of irrigation water, deterioration of some structures and water logging problems on some farms (Berhanu, 2006). Poor irrigation scheduling/crop-water-requirement balance; inappropriate irrigation methods are widely recognized (MoA, 2011).

5.4 Market related constraints

When the respondents were asked about market availability and access for their irrigation-based product about 47 % of them responded that they are facing market problem while about 53% said they have not faced marketing problem (table4.2.7).

Table.15 Responses of farmers about marketing problem

Irrigation scheme	Total respondents	No	%	No	%
Mush	53			53	100
Feleku	26	26	100		
Weynabchu	21	21	100		
Total	100	47	47	53	53

Price instability and lack of market are almost invariability confirmed as conspicuous major constraints to irrigated agriculture. Marketing cooperative were conspicuously missing or proved to be too ineffectual to reduce risks arising from price instability and marketing problems (Adugna, 2014) . The Mush irrigation schemes farmers did not face market problem because they were organized under water user cooperatives (WUC) and individuals products supplied to the cooperatives. The marketing committees of cooperatives search market opportunities and help communities sell with a good price However, Feleku and Weynabchu irrigation scheme farmers are totally lack market access and forced to sell their products with low price. There are also cases where they loss all their produce (perishable products) due to lack of market and storage facilities.

5.5. Irrigation water conveyance system problem

The absence of water canals in the schemes affects the transportation of water from the source to irrigation plots. Most of the canals are exposed and not lined causing water to seep and evaporate. In some cases, the water also breaks canals and got lost (not serving the intended purpose) as shown in Figure 21.

Figure.20 Photos showing canal problem

The important reason to construct lined cannels can be the reduction in water losses as we can understand from the study area water losses in unlined irrigation canals can be high. The lining irrigation canal has the benefits: reduction in seepage losses from canals reaching water table and raising it result in waterlogging and reduction yield; reduction evaporation and transmission losses due to reduce exposed areas; reduction erosion and theft of water by cultivators is stopped (http://theconsructor.org and http://linedcanals,worldpress.com ,2016).

CHAPTER SIX

6. Policies and by-laws

6.1. Policies related to small scale irrigation

The broad Ethiopian water resource management policy (1999) consists of eleven irrigation sub-policies, under these sub-policies five points are directly related to development of mall scale irrigation (SSI). Those are:

- Ensure the full integration of irrigation with the overall framework of the country's socio-economic development plans.
- Recognize that irrigation is an integral part of the water sector.
- Promote decentralization and users-based-management of irrigation systems taking account of the special needs of rural women in particular.
- Support and enhance traditional irrigation schemes by improving water abstraction, transport systems and water use efficiency
- Ensure the prevention and mitigation of degradation of irrigated water.

The current thesis research examined the above five sub-policies with 100 respondents and 18 FGD participants in the study area. The first listed sub-policy is implemented in the study area in integration with soil conservation and other natural resource development plans. Decentralization and user based irrigation water management is highly implemented and experienced for long time. Participation of women in irrigation practices and water management is increasing from time to time and is showing good result. Irrigation practices are still traditional. Farmers use soil canal and flood irrigation method. As a result, this could not achieve water use efficiency. A policy related with water use efficiency implementation is very weak. Prevention and mitigation of irrigation water degradation is at an infant stage in the kebele, NGO’s and WUC prepare schedule for irrigation user, maintain and built canals and develop springs. Implementation of the last two sub-policies was much better than the others (Figure 22).

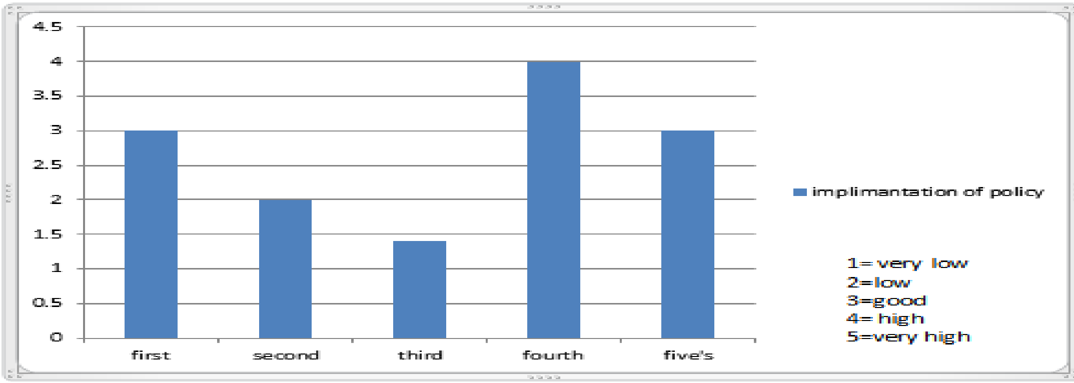


Figure 21.Implementation status of sub-policies

6.2. By- laws

There are administrative by-laws that were developed by water users. WUC has developed by-laws about water management, schedule of water utilization, conflict management, canal maintenance and duties and rights of users.

a) Principles of water user's cooperatives are the following:

- There is no discrimination to member of WUC based on sex, religion, politics and social situation.
- The cooperative is democratic organization lead by good participant members.
- The cooperative can make agreement and access credit from government and NGOs with recognition of members. Insertion

b) Duties of irrigation water user

- Should implement the decision of committees
- Pay irrigation water service payment
- Protect the resource of cooperatives
- Conserve and maintain irrigation canal
- Protect and monitor pests and weeds

c) Water service payment

- Any irrigation water user should pay service payment
- Water service payment is needed for maintenance of canal, guard and for other outcomes.
- The payment is done before production

d) Conflict resolving/management system

- Two disagreed persons or group select each two elder persons; the third elder person is selected by both.
- If the problem is not solved by three elder persons the case is proceeded to judgment committee of WUC
- When the conflict is beyond power of WUC, the caseis reported to concerned government part.

6.3. Contribution of SSI for gender and nutrition

Women play a central part in the provision, management and safeguarding of water (WEDI, 1992). Irrigation can provide benefits to rural women by enabling women to increase their cash incomes and diversify family nutrition and food sources. Women may benefit from irrigation by producing crops around their farm land and home as home garden crop and. These produced crops then help the women as income source. In addition the production of these crops using irrigation as home garden will reduce finance dependency of women on men and promote gender equality in rural areas. The participation of women in water management and irrigation practice has become increasing year to year. From the total household number of sample scheme 29.7% are female household. Respondents were asked to understand whether women are beneficiary from irrigation farming. About 75% of respondents replied ‘Yes’ but the remaining said ‘No’ (Table 16)

Table.16. Contribution of irrigation for women

Scheme	Total No of respondent	Yes		No	
		No	%	No	%
Mush	53	48	48	5	5
Feleku	26	20	20	6	6
Weynabchu	21	7	7	14	14
Total	100	75	75	25	25

As can be seen from the Table 14, in mush irrigation scheme 48% of the respondents, Feleku scheme 20% and weynabchu scheme 7% are replied 'yes". However, the remaining respondents of each scheme replied "no'. The survey from the current research identified benefits that could be achieved by women farmers; those are increasing their income, enable to show their ability in outhouse works and insure their household food security. For instance W/ro Shibre Weldesilase (Figure 23) is model member of Mush WUC, she could produce high amount of products as compared to other members and rewarded by WUC in the past production year. She already managed to improve her income and tried to improve her food security.

Figure.22 W/ro Shibre Woldesilase on her irrigation plot

Nutrition is also the other aspect that this study tried to understand its relation with irrigation. The farmers in the study area mainly grew potato, bean, garlic, shallot, and lentil under irrigation farming. Growing vegetables (cabbages, lettuce and others) and fruits are not common in the study area. However, 12% of respondent families are under five year age and need balanced nutrition. When respondents asked as irrigation farming could help to insure nutrition of their families, 85% said yes but the remaining could not insure their nutrition requirement.

Table17.Contribution of irrigation for nutrition

Scheme	Total number of respondents	Yes		No	
		No	%	No	%
Mush	53	45	84.9	8	15.1
Feleku	26	22	84.6	4	15.4
Weynabchu	21	18	85.7	3	14.3
Total	100	85	85	15	15

Farmers in the study area describe the constraints i.e. seasonal water shortage that limit growing of vegetables. Though farmers don't grow vegetables, they sell what they grow in their farms and buy nutrition rich food for their families.

CHAPTER SEVEN

7. CONCLUSION AND RECOMMENDATION

7.1. Conclusion

There are five rivers and nine springs in Gudo Beret and the surrounding areas. However, due to anthropogenic (poor management of the surface water resources and population pressure) and climatic factors the rivers and springs are drying from time to time. Measures that minimize the drying of the water sources are necessary to support livelihoods of the smallholder farming communities. Strengthening the current country and regional level move on natural resources management through integrated watershed management is one of the options to address the water and soil nutrient depletion related challenges. Improving water uses efficiencies through capacity building and introducing high value crops and agronomic practices would ensure maximum benefit in terms of cash, food security and nutrition for the communities that partially or fully dependent on irrigated agriculture. Collective actions on the management of the rivers and springs, and strengthening the institutional arrangements of the irrigation water use association groups would help to minimize conflicts and ensure sustainable use of the water and other natural resources. Women and youth are part of the society that accounts reasonable proportion from the total population of the study area. For instance, 30% from the total households are women. Enhancing participation and engagement of women and youth in the irrigation agriculture would avoid biases on benefit sharing among the different social groups.

7.2. Recommendations

Based on the results of this study the following recommendations are derived for further consideration.

- In the upper watershed there should be a strong soil and water conservation work to resolve water shortage problem in lower watershed.
- GIS based irrigable area mapping consider only main land criteria's but need to examine water potential with crop water requirement to implement irrigation on the study area .
- The training and awareness creation about irrigation methods, technology and water management should be strengthened by government and non-governmental organizations.
- To increase water use efficiency and productivity; government and NGO'S should provide credit service, construction of canal and professional advice for farmers.
- MoWR need to examine implementation of its Irrigation Policies at lower government level and give support for SSI users.

REFERENCE

Adugna Eneyew Bekele, (2014) Five Key Constraints to Small Scale Irrigation Development in Ethiopia: Socio-Economic View, Jimma University, College of Agriculture & Veterinary Medicine, Department of Agricultural Economics & Extension P.O.Box 307 Email: adugna_e@yahoo.com Accepted 23 September 2014.

Amanda Robb, (2003) Definition & Types of Irrigation, © copyright 2003- 2016 Study.com, http://study.com/academy/lesson/definition/-types-of-irrigation.html

Anne Kuria, enevieve Lamond, Tim Pagella, Aster Gebrekirstos, Kiros Hadgu and Fergus Sinclair,(2014) Local Knowledge of Farmers on Opportunities and Constraints to Sustainable Intensification of Crop Livestock Trees Mixed Systems in Basona Woreda, Amhara Region, Ethiopian Highlands

Avinash Kumar, O.P.Dubey, S.K.Ghosh, (2014) GIS Based Irrigation Water Management IJRET: International Journal of Research in Engineering and Technology ISSN: 2319

Berti, P. R., J. Krasevec, and S. FitzGerald, (2003) "A Review of the Effectiveness of Agriculture Interventions in Improving Nutrition Outcomes."Public Health Nutrition 7 (5): 599–609.;Laia

Berhanu Gebremedhin and D. Peden , (2002) Policies and institutions to enhance the impact of irrigation development in mixed crop–livestock systems, International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia

CAP-NET, GWA (2006), Why Gender Matters: a tutorial for water managers, Multimedia CD and booklet. CAP-NET International network for Capacity Building in Integrated Water Resources Management, Delft

CHF L-SAP (2010) Impact Assessment of Small-Scale Pump Irrigation in the Somali Region of Ethiopia, Addis Ababa, Ethiopia.

Chisholm and Hugh, (2016), Irrigation, Encyclopedia Britannica,(11th ed. of 1911). Cambridge University Press. https://en.m/wikipedia.org/wiki/irrigation

Dessalegni Rahmato, (1999) Water Resource Development in Ethiopia: Issues of Sustainability and Participation, Forum for social studies, Addis Ababa, Ethiopia

Domenech& Claudia Ringler (2013) ,The Impact of Irrigation on Nutrition, Health, and GenderA Review Paper with Insights for Africa south of the Sahara IFPRI(international food research institution) Discussion Paper01259April2013.

Eduardo Antonio Holzapfel Hoces, José Luis Arumí, Antonieta Rodríguez & Vital Pedro da Silva Paz(2012) Water Resources and Irrigation Management Universidade Federal do Recôncavo da Bahia, Cruz das Almas, BA Instituto Nacional do Semiárido, Campina Grande, PBv.1, n.1, p.7-14, Sept-Dec, 2012

Eltaib Saeed, Rowshon, M.K Amin and M.S.M.(2004) GIS-Based Irrigation Water Management for Site- Specific Management, http://www.unoosa.org/pdf/sap/2004/sudan/presentations/03-05.pdf

FAO (2003), Agriculture, food and water, a contribution to the World Water Development Report, 92-5-104943-2;

FAO, (1985) Guidelines: Land Evaluation for Irrigation Agriculture, Soil bulletin No 55, Rome

Floriane Clement (2012), Gender and Water Management Organizations In Bangladesh, International Water Management Institution

Igor A. Shiklomanov, (2000) Appraisal and Assessment of World Water Resources, Water International, 25:1, and-11-32, DOI: 10.1080/02508060008686794

ILRI, (2014/2015) International Livestock Research Institute (ILRI),P.o.Box 5689. Addis Ababa, Ethiopia.

John P. Wilson, Helena Mitasova, Dawn J. Wright, (2000) Water Resource Applications of Geographic Information Systems URISA Journal • Vol. 12, No. 2 • Spring 2000

Karina Schoen, (2007) A Global View on Irrigation Development, gold University of Nebraska, Lincoln, kschoengold2@unl.edu

Mahmoud Y, (2010) Geographical information system applications in groundwater assessment and Monitoring Case study: Gaza Strip, Water Information Department, Palestinian Water Authority mahlatif@yahoo.com

MDA, (2015) Irrigation Practices, Minnesota Department of Agriculture, http://www.mda.state.mn.us/protecting/conservation/practices/irrigation.aspx.

MDRICRI, (2011) Water Governance Assessment: The Case of the Mekong Delta, Can Tho University, Mekong, Netherlands

MANRMD, (2011), Small-Scale Irrigation Situation Analysis and Capacity Needs Assessment Addis Ababa, Ethiopia.

Meron Tariku Ayne (2007) Surface Irrigation Suitability Analysis of Southern Abbay Basin By Implementing GIS Techniques, Addis Ababa University Technology Faculty, Addis Ababa, Ethiopia.

MoWR, (1999), Ethiopian Water resource Management policy

NBDC (2011) The Development of Key National Policies with Respect to Rainwater Management in Ethiopia: A review, Prepared by Ethiopian Economics Association, Technical Report 2, CGIAR Challenges program on Water & food Nile, July 2011

Negash W., (2004) GIS Based Irrigation Suitability Analysis A case Study of Abaya-Chamo Basin, Southern Rift Valley of Ethiopia, Arba Minch University, Institute of Water Technology, Arba Minch, Ethiopia.

NEH, (1997), Irrigation Guide Selecting an Irrigation Method, Part 652, Chapter 5, 210-vi.

OMICS, (2015) Importance of Irrigation Management,http://www.omicsonline.org/irrigation-management-importance.php.

Paul A. Longley, Ichael F. Goodchild, David J. Maguire, David W. Rhind (2005) Geographical Information Systems and Science, Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England.

Paul klee & Chosen Site, (2001) Principle Of Geographic Information System, The International Institute for Aerospace Survey And Science, Netherland.

Pieter van der Zaag, (2003) Basics of Water Resources, Water Net, in collaboration with the Centre of Conflict Resolution CCR (South Africa), the Instituto Superior de Relações Internacionais ISRI (Higher Institute of International Relations) (Mozambique), Catalic (The Netherlands/Mozambique), UNESCO-IHE Delft (The Netherlands) and the University of Zimbabwe (Zimbabwe)

P.S. Fortes a, A.E. Platonov b, L.S. Pereira, (2015) GIS based irrigation scheduling simulation model to support improved water use Agricultural, GISAREG—A, Engineering Research Center, Institute of Agronomy, Technical University of Lisbon, Tapada da

Rahel Derbe, (2008) Institutional analysis of water management on communal irrigation systems: the case of atsbi wemberta district in tigray region and ada'a district in oromiya region, Addis Ababa University School of graduate studies . Ajuda, 1349-017 Lisbon, Portugal

Saskia Ivens,Consultant, Gender and Water Alliance (no date), Presentation 'Gender Perspectives in Integrated Water Resources Management'.

Seleshi B. Awulachew and Aster Denekew Yilm (no date) Status, quo analysis, Characterization And Assessment of Performance of Irrigation in Ethiopia International Water Management Institute for Nile, Addis Ababa, Ethiopia.

Seleshi Bekele Awulachew, (2010) Irrigation potential in Ethiopia Constraints and opportunities for enhancing the system, International Water Management Institute

Seleshi Bekele Awulachew and Mekonnen Ayana, (2011) Performance of Irrigation: An Assessment at Different Scales in Ethiopia, Volume 47 (S1), Pp. 57–69c Cambridge University Press 2011 Doi: 10.1017/S0014479710000955.

Solomon Cherre (2001), Irrigation Policies, Strategies and Institutional Support Conditions in Ethiopia, Ethiopian Water Sector Development program, MoWR solomoncherie@yahoo.com

TOTAL EDEN web site (2016), Irrigation Systems, Different Types of Irrigation, Copyright © 2010 TOTAL EDEN Pty Ltd ABN: 47 010 118 895. All Rights Reserved , Web Design by Salsa Digital, https://www.totaleden.com.au

UNDP, 2002 women and water management: an integrated approach http://www.unep.org /PDF/.../chapterfive.pdf.

World Meteorological Organization, (2012) Technical Material for Water Resources Assessment, CH-1211 Geneva 2, Switzerland

APPENDICES

Appendix I: collected GPS points in the study area

Springs name	Latitude	Longitude
Shinet	573327	1083657
Weynabchu	574515	1082783
Chig'gni Tabita	574542	1082682
Salasfa	572693	1081968
Beteskian Amba	572386	1081027
Mukechit	573934	1080867
Ahaya	573133	1080387
Shola	570897	1082055
Weldeab Ager	577024	1081014

Appendix II: Questionnaire survey Designed for small scale irrigation

Research title: Assessment of Water Resources, Irrigation Technologies and Collective Action and Related Issues: the case of Gudo Beret and surrounding areas, North Shewa Ethiopia.

Dear respondent!!!

The result of this thesis will have significant contribution in improving the present irrigation water use and management efficiency and performance of your kebele. It also helps to identify the major constraint, of small scale irrigation. Therefore, to attain these objectives, the research respectfully requests your genuine contribution in providing the required data.

Thank you for your cooperation!!!

General instruction: put tick mark (✓) in front of the appropriate answer to indicate your response from the given choice, for the open ended questions, the respondents are required to write the response in the given space.

I. Survey area description

1.1.**Region – Amhara**

1.2. Zones – North Shewa

1.3. Woreda – Basona Worena

1.4. Name of the sample kebele's to which respondent belongs

____

1.5.Name of WUA/WUC the respondents belongs,

____

1.6.Total command area of the WUA/WUC,

____

1.7.Total household members of the WUA/WUC,

____

1.8.Relative site of the respondent plot in the WUA/WUC:

A. Upper stream ☐ B. middle stream ☐ C. lower stream☐

II. Background Information

2.1.Age _ __ _ _ _ _ _ _ _ _ _

2.2.Sex _ _ _ _ _ _ _ _ _ _ _ _

2.3.Educational background:

Illiterate ☐

Primary (1-8) ☐

Secondary ☐

Certificate and above ☐

2.4.Marital status:

Single ☐

Married ☐

Divorced ☐

Widow ☐

2.5.Total house hold size:

Age	Sex (in number)		
	Male	Female	Total
<5			
6-14			
15-65			
>65			
Total			

2.6.Religion: A. Orthodox ☐ B. Muslim ☐ C. protestant ☐

III. Land holding and farming condition

3.1. size of land owned by household: A. <0.25 ha ☐ B. 0.25-0.5 ha ☐

C.0.5-1 ha ☐ D. >1 ha ☐

3.2. How much of your total farmland in proportion of land (in hectare) do you cultivated under?

A. Irrigation farming__________________

B. Rainfed farming __________________

3.3.What are the major crops you cultivated under the rainfed system

No	Crop type	Yes	No
1	Bean		
2	Barley		
3	Pea		
4	Wheat		
5	Lentil		
6	Other		

3.4.What condition do you set as criteria to select the major irrigation crops?

No	Type of crop	Yes	No
1	Potato		
2	Onion		
3	Vegetable		
4	Fruits		
5	Lentil		
6	Other		

3.5.What was a criterion to select major crops under irrigation farming?

A. Price on market ☐ B. for household consumption ☐

C, water requirement of crop ☐ D. other ____________________________

IV. Irrigation farming experience

4.1.How do you organize in this WUA/WUC first?

A. Due to your own request voluntarily ☐
B. Due to the influence of your friends ☐
C. Due to the influence of the local administration ☐
D. Others_____________________________________

4.2.What factors were motivated or forced you to involve in practicing irrigation farming?

A. climate uncertainties ☐ B. to increase income ☐

C, to insure food security ☐

4.3. How do you get your plot to be member of the WUA/WUC first

A. From family ☐ B. from kebele ☐ C. rent ☐
D. other ___________

V. Irrigation water use and related issues

5.1.Did your irrigated field totally using water from the conveyance systems of WUA/WUC?

A. Yes ☐ B. No ☐

5.2.If your answer for question '5.1' is 'No':

A. From where do you get the water to irrigate this field?
A. river ☐ B. spring ☐ C. haul ☐ D. other _________________________
B. How do you convey the water to irrigated field?
A, by man power ☐ B. using pump ☐ C. trough canal ☐
D. other_______

5.3.Does irrigation water is sufficiently available in all seasons to your WUA/WUC?

A. Yes ☐ B. No ☐

5.4. If your answer for question '5.3' above is 'No':

A. In which season the water shortage usually occurs?

A, November–December ▭ B. December –January ▭ C. January-February▭

D, February-March ▭ E. March-April ▭ F. April –May ▭

B. What are the possible factors for the prevailing water shortage?

A, sunny season ▭ B, water applied for other utilization ▭

C. number of user increase ▭ D, inappropriate utilization ▭

E, problem of water canal ▭ F, other ___________________________

5.5.Do you think that the problems of water shortage in the area need institutional intercession measures?

A. Yes ▭ B. No ▭

5.6. If answer is Yes for question '5.5'; in which intervention way is good

A. Training on water management ▭ B. canal construction ▭ D. other_________

VI. Issues Related to Water Application and Technology Choice

6.1. Among the following irrigation methods which one is most commonly used in your WUA/WUC? If necessary rank them.

A. Flood ▭ B. Sprinkler ▭ C. Drip ▭

6.2. Do your methods of irrigation the same for all irrigated crops?

A. Yes ▭ B. No ▭

6.3.What was a criteria to select irrigation methods

A. adapted in your area ▭ B. easy technology ▭ C. to save water ▭

D. because of climate ▭ E. other ______________________________

6.4. To improve your productivity, do use agriculture technologies?

A. Yes ▭ B. No ▭

6.5. If answer is 'yes' for question '6.4'; which technology use in your irrigation plot?

A. fertilizer ▭ B. pesticide ▭ C. weedicide ▭ D. special seed ▭

E. other ____________________________

6.6. Availability of fertilizer:

A. excellent ☐ B. very good ☐ C. good ☐ D. bad ☐ E. very bad ☐

6.7. Availability of pesticide:

A. excellent ☐ B. very good ☐ C. good ☐ D. bad ☐ E. very bad ☐

6.8. Availability of weedicide:

A. excellent ☐ B. very good ☐ C. good ☐ D. bad ☐ E. very bad ☐

VII. Irrigation policy implementation and institutional by law

7.1. In your kebele irrigation plan implement by cooperate with other social and economic plans? A. Yes ☐ B. No ☐

7.2. Implementation of de-centralized water management and enable to women to participate and be beneficiary.

A. Very high ☐ B. high ☐ C. intermediate ☐ D. low ☐ E. very low ☐

7.3. Irrigation practices implemented as major Water resource management work in your kebele:

A. Very high ☐ B. high ☐ C. intermediate ☐ D. low ☐ E. very low ☐

7.4. Works on improving traditional water utilization supports:

A. Very high ☐ B. high ☐ C. intermediate ☐ D. low ☐ E. very low ☐

7.5. Supports in protection and conservation of irrigation water degradation:

A. Very high ☐ B. high ☐ C. intermediate ☐ D. low ☐ E. very low ☐

7.6. Irrigation water cooperatives have law? A. Yes ☐ B. No ☐

7.7. When in preparation of WUC law members were participated?

A. Yes ☐ B. No ☐

7.8. Implementation of law in WUC:

A. Very high ☐ B. high ☐ C. intermediate ☐ D. low ☐ E. very low ☐

VIII. Gender and Nutrition

8.1.Man and women are equally participating in irrigation practice?

A. Yes ☐ B. No ☐

8.2. Women can be beneficiary from irrigation farming?

A. Yes ☐ B. No ☐

8.3.If answer is 'yes' for question '8.2'; in which way?

A. Increase their income ☐ B. insure their food security ☐

D, show their ability on farming work ☐

E. other ________________________

8.4.Participating on irrigation farming help you to insure your family nutrient requirement? A. Yes ☐ B. No ☐

8.5. If the answer is yes for question '8.4'; how irrigation farming help you to insure your family nutrient requirement?

A. Grow vegetable and fruit ☐ B. exchange products by nutrient food ☐

C, other ____________________________

8.6. Did you face marketing problem? A. Yes ☐ B. No ☐

IX. Extension service

9.1.What type of support do you get from governmental and NGOs

A. Training ☐ B. professional advice ☐ C. technologies ☐

D. construction of canal ☐ E. credit ☐

F. other _________________________________

9.2.Do you think the extension service and support what you get before were sufficient?

A. Yes ☐ B. No ☐

9.3.If the answer for question '9.3' is 'No'; which service is you need?

A. Training ☐ B. professional advice ☐ C. technologies ☐

D. construction of canal ☐ E. credit ☐

F. other _________________________________

Thank you!

Appendix III: Field Survey Check List

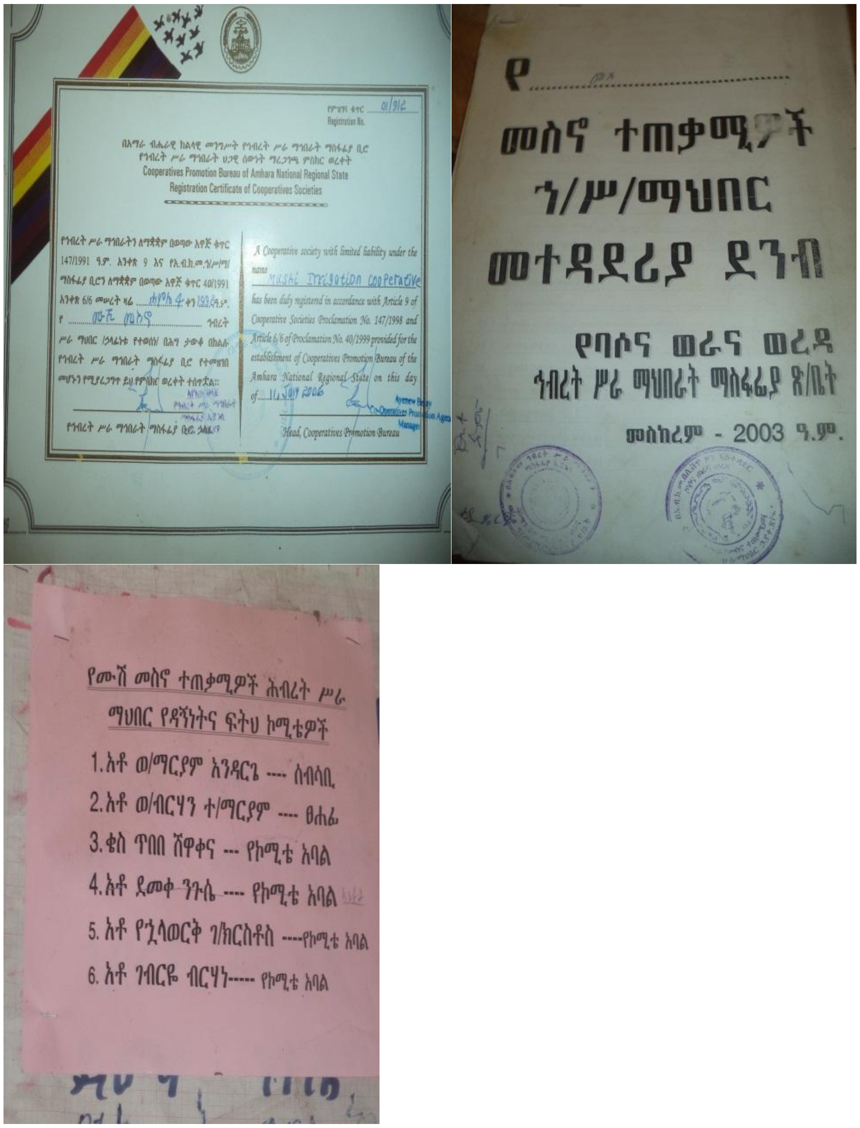
1. **Geo-Spatial information**
    - X & Y Coordinates of areas (GPS)
    - Identifies major Land use/cover
    - Ground identification of features (water source) location
    - Identification of Irrigable area location
2. **General condition of farming practices**
    - Crop cultivation practices and pattern:
        - Rainfed
        - Irrigated
    - Crop selection criteria
        - Rainfed
        - Irrigated
3. **Irrigation water use practices**
    - Water supply sources
    - Physical layout of irrigation system
        - Water conveyance
        - Canal alignment
    - Water distribution and application
        - Method of irrigation for various crops
        - Water distribution schedule
        - Irrigation interval
    - Crop cultivation pattern and water application
    - Farm input usage and cropping intensity
4. **Irrigation management practices:**
    - Roles and responsibilities of committee members
    - Water management rule
    - conflict resolving rule
    - marketing rule

Appendix IV: Photos

Photos of field survey in the study area

Field survey in the study area

Focus group discussion in the study area



Documents of water user cooperatives

Hydrological Components of Study Area

Month	Mean Rain fall (mm)	Mean T° (°C)	Relative humidity	Sunshine hour (hrs)	Evapotranspiration (mm)
Jan	13.5	11.6	12.1	220	0.85
Feb	29.5	12.4	13.6	272	0.75
Mar	66.5	12.8	12.4	226	0.88
Apr	64.5	14.4	13.4	289	0.85
May	55.5	13.8	13	204	0.86
Jun	75.5	13.6	14	168	0.76
Jul	308.5	13.1	11	273	1.10
Aug	257	11.8	12	113	0.87
Sep	119	11.6	9.9	214	1.20
Oct	35.5	10.4	9.5	260	1.10
Nov	18.5	10.6	9.3	254	1.10
Dec	7.5	10.9	10	232	1.00
Total	1051	147	140.2	2725	11.26

$PEm=16Nm\,(10Tm/I)^{a}$

Where; PEm: monthly evapotranspiration, monthly

Nm: monthly factor of day light, Tm: the monthly mean temperature in ^{o}C,

I: annual humidity, a= 0.000000675 I3 -0.0000771 I2 +0.01792 I+ 0.49239

and water balance equation (P-E)