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ASSESSMENT OF THE MANAGEMENT AND EXPANSION OF SMALL HOLDER PUMP IRRIGATION IN LOWER GUMARA RIVER, LAKE TANA BASIN, ETHIOPIA

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FACULTY OF CIVIL AND WATER RESOURCES ENGINEERING

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Bahir Dar, Ethiopia

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Masters of Science in Hydraulic Engineering in the faculty of Civil and Water Resources Engineering

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DECLARATION

I, Habtam Tadele Simeneh, hereby declare that this thesis submitted for the partial fulfillment of the requirements for the Master of Science in Hydraulic engineering, in the original work done by me under the supervision of Dr. Mekete Dessie and it has not been published or submitted elsewhere for the requirement of a degree program to the best of my knowledge and belief. Materials or ideas of other authors used in this thesis have been duly acknowledged.

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This thesis has been submitted for examination with my approval as a university advisor.

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DEDICATION

I dedicate this thesis manuscript to all my families for their love and partnership in the success of my life and I dedicate this work to my beloved brothers and sisters Degu, Dr.Yichalal, Asmaru and Beletu for their economic and moral support during my studies.

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ABSTRACT

The main objective of this study is to assess the management and expansion of small holder pump irrigation along the course of lower Gumara River. To achieve the specified objectives, both primary and secondary data sources were used. The primary data were collected from field investigations and observations, sampling of 98 randomly selected respondents through semi-structured questionnaire. Secondary data were also gathered from different sources like office of Agriculture, Development Agents, Reports, published and unpublished sources. Land use/cover change analysis like ArcGIS and ERDAS were used to understand the expansion of small holder irrigation along the River course. CROPWAT model has been also employed to estimate the irrigation requirements of the crops commonly cultivated by the irrigators. The results of the study show that from 2001 to 2017, irrigated agricultural land increased by 65.25% (from 322.82ha in 2001 to 2307.71ha in 2017), non-irrigated agricultural land decreased by 53.48%, forest/shrubs decreased by 3.12% and flooded agricultural land decreased by 8.65 %. Generally, there was high expansion of irrigation along the lower course of Gumara River. The irrigation requirements (in mm) for Onion, Tomato, Potato and Maize are 338.1, 322.1, 331.3, 249.5 respectively. The annual irrigation water consumption from the river increased from 1733624 m^3 in year 2001 to 12392980 m^3 in year 2017 for irrigation, whereas the average annual supply of water for the irrigation period (Nov-June) from the River is 51289236 m^3 (nearly constant supply). However, supply was short of demand in April and this resulted in competition for water in recent times. Small holder motor pumps were found to be the main technologies to draw water to the fields from the River. Based on this study, insufficient water source, lack of awareness, cost of water lifting technologies, materials and services, markets and finance are the major factors influencing the adoption of the motorized water pump in this area. As the expansion of irrigation continues, it is recommended to work on improving the efficiency of water utilization, to look for alternative water sources (groundwater, water harvesting) and to raise the awareness of the irrigators on the value of water among others.

Keywords: Small holder, Motor pump irrigation, Technology adoption, Remote Sensing, GIS, ERDAS, CROPWAT.

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LIST OF ABBREVIATIONS

ANRS	Amhara National Regional State
AoI	Area of Interest
BDU	Bahir Dar University
BoA	Bureau of Agriculture
CWR	Crop Water Requirement
DAs	Development Agents
ERDAS	Earth Resource Data Analysis System
ET_c	Crop evapotranspiration under standard conditions
ET_o	Reference crop evapotranspiration
FAO	Food and Agriculture Organization
GCP	Ground Control Point
GIS	Geographical Information System
GPS	Global Positioning System
ha	Hectare
HH	Household
IWMI	International Water Management Institution
Km	Kilometre
l/s/h	Litter per second per hectare
LULCC	Land Use Land Cover Change
NGO	Non-Governmental Organization
OLI	Operational Land Imager
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WLTs	Water Lifting Technologies

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1. INTRODUCTION

1.1 Background

The increasing need for crop production due to the growing population in the world is necessitating a rapid expansion of irrigated agriculture throughout the world (Awulachew et al., 2005).

In recent years, small scale private individualized irrigation technologies have taken off, first in Asia, and more recently in Sub-Saharan Africa. This is due to a combination of factors including increased availability of low-cost pumps, sprayers and drip systems, and urbanization that creates local markets for high-value products and in some cases global markets (Burney et al., 2013; Giordano and de Fraiture, 2014; Namara et al., 2011). Although there are exceptions, the private irrigation projects in Niger supported by the World Bank (Abric et al., 2011), in Africa much of this development has occurred with no formal government investments or even policy attention. The significant impacts of pump-based irrigation in terms of poverty reduction and higher agricultural productivity are impressive in both Asia and Africa (Naylor, 2012; Shah et al., 2013). However, the rise of individually owned pump-based irrigation has led to new problems.

The majority of population of Ethiopia is dependent on rain fed agricultural production for its livelihood. However, estimated crop production is not close to fulfil the food requirements of the country (Mosisa, 2016). Irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia (Seleshi et al., 2010). A study also indicated that one of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales (whether small, medium or large) and options (diversion, storage, gravity, pumped, etc.) (Mosisa, 2016).

Amhara Region has a vast water resource potential in surface water and ground water, international river like that of the Blue Nile draining into the neighbouring countries and other rivers (Mekonnen et al., 2016). Therefore, there is a good opportunity to use and develop irrigation technologies. The ANRS BOA were involved for the adoption and dissemination of motorized water pump technology. However, the extents of which farmers have adopted these motorized water pumps have not been studied and the factors affecting the adoption of motorized water pump were not yet known.

Rural people in Fogera depend on agriculture for their livelihoods. It is largely based on smallholder rain fed farming. Farmers grow various crops depending on the wet and dry seasons. The main cultivation season is the wet season, from June to September (Virtanen et al., 2011). However, the reliance on rain fed agriculture is often problematic. It is vulnerable to rainfall uncertainties, i.e. erratic rainfall and drought. Therefore, in recent years, small-scale irrigation has expanded in Fogera. Farmers practice both motor pump irrigation and traditional irrigation, Pumps are owned and used by individual farmers (Dessalegn and Merrey, 2015).

Even if this motorized technology supplied and distributed to farmers there is low level of knowhow and limited practical skills of farmers in irrigated agriculture and agricultural irrigation technologies with predominated traditional and inefficient water management practice. Therefore, the irrigation sub-sector needs to be supported by appropriate irrigation technologies and related research findings that will assist farmers engaged in irrigated agriculture to increase production and productivity of irrigated crops. The importance of irrigation development, particularly in the peasant sub-sector needs prime consideration to raise production to achieve food self–sufficiency and ensure food security at household level. The irrigated agriculture can play a vital role in supplying sufficient amount and the required quality of raw materials for domestic agro-industries and increase export earnings.

Fogera and Dera woredas, where the study focuses, is endowed with diverse natural resource, with the capacity to grow different annual and perennial crops. Two major rivers are of great importance to the Woredas, Gumara and Ribb. They are used for irrigation during the dry season. Major types of vegetable crops grown in the area include potato, onion, tomato, hot peppers and some leafy vegetables (Akalu, 2007). In the study area irrigation technologies and management were introduced by Koreans in 1988-1992 G.C specifically at Jigna kebele by using Gumara River for developing and producing rice and vegetables (Getahun, 2012).

Currently, there are considerable irrigation activities following the different river courses. In recent times, it has become a common practice to use small motorized pumps to lift water from the rivers to the fields for irrigation. The lower Gumara River (downstream of Wanzaye area) reach is a typical instance for an increasing practice of irrigation following the river courses using small motorized pumps. This study therefore tries to assess the management and expansion of small holder pump irrigation in lower Gumara River reach, Lake Tana Basin.

1.2 Statement of the problem

Ethiopia is experiencing a rapid population growth and the great challenge is that the growth of the agriculture sector is not proportional with the rate of population growth and as a result the sector is unable to fulfil the food requirements of the whole nation and even not satisfying the need of domestic industries in supply of raw materials with quantity and quality of produce (Mosisa, 2016).

The Gumara River is the main river flowing through borderline to the Fogera and Dera woredas flood plain. Around the plain near to the river there is expansion of small holder motor pump irrigation. This motor pump irrigation system was introduced during the Derg period, around in 1970s' and continue still now. Nowadays, the need of farmers for irrigation has highly increased in the area. But in the study area, the extent of the expansion trends and factors influencing the adoption of the motorized water pump are not clearly known, there is technical knowledge gap on how are the small holder irrigations managed and whether the available water can sustain the irrigation needs or not.

Studies on small-holder farmer-based irrigations are not sufficiently done, particularly such studies on the catchments of Gumara River are absent. Hence, this study aims to investigate the expansion of such small holder irrigation activates along the lower reach of Gumara River, explores the existing small holder water managements in comparison with the estimation of the irrigation requirements and identifies bottlenecks for the sector in this area.

1.3 Objective of the study

The overall objective of this study is to assess the management and expansion of small holder pump irrigation in lower Gumara River.

1.3.1 Specific objectives

- To assess the current extent of small holder pump-based irrigation in lower Gumara River reach.
- To investigate factors influencing the adoption of the motorized water pump for irrigation in the study area.
- To identify management practices for the small-holder motorized pump irrigation (estimate irrigation demand for the traditional irrigation, determine the available supplies and analyse the balance of irrigation needs and supplies) to improve water use efficiency.

1.4 Research questions

- How are the extent of the practices and expansion trends of small holder pump irrigation in the study area?
- How are the small holder irrigations managed and what factors influence the adoption of the motorized water pump for irrigation in the study area?
- What measures have to be undertaken in order to improve the water use efficiency for small holder motorized water pump irrigation system?

1.5 Scope and Limitations of the Study

The study was conducted along the lower reach of Gumara River on small holder motorized pump irrigation following the river course as close as 300 meters to the right and left side of the River, downstream of Wanzaye town, for 12 kebeles of two woredas in South Gondar zone of Amhara National Regional State (ANRS), Ethiopia.

The field survey and observation has been carried out using GPS and semi-structured interview technique was employed from 98 households motor pump user farmers from four kebeles of Fogera and two kebeles of Dera woredas were selected randomly from 4848 motor pump user households. Land use/cover study has been undertaken, images for the study years were analyzed using GIS and ERDAS. CROPWAT model has been undertaken on crops commonly cultivated by the irrigators (Onion, Tomato, Potato and Maize) in the area.

1.6 Significances of the study

The study shall have significant contribution to understand the current extent, factors influencing the adoption of the motorized water pump and management practices of the small-holder pump-based irrigation. It will give information for further improvement and investment approaches for implementing agents (Governmental organizations, Non-governmental organizations, Research Centres, etc). It can also be used as a benchmark and entry point for development works and future studies. Therefore, this study will be expected to increase the understanding and provide up to date information of smallholder pump-based irrigation along the lower Gumara River course for the people in the area and the agricultural experts who are engaged in the irrigation activities.

1.7 Layout of the Thesis

This paper has five chapters: chapter one is an introduction section where the background, statement of the problem, objectives of the study, research questions, scope and limitation of the study, significance of the study and layout of the thesis are discussed. In chapter two, review of related literatures where irrigation development in Ethiopia, surface irrigation methods, irrigation technology adoption, emerging competition and conflicts over water, land use/cover changes and expansion of irrigation, application of remote sensing, ERDAS and GIS, CROPWAT Model and previous studies in Ethiopia on expansion of agricultural land. Materials and methods of the study are presented in chapter three in which study area and data availability, conceptual framework of the study, data collection methods, data quality analysis, existing crop production and management of the area, Image processing for land cover change, Image classification and CROPWAT model. Chapter four describes the result and discussion which are land cover changes in the study period, crop water requirement, irrigation scheduling, relevant interview response and field survey results were presented. Finally, in chapter five, conclusion and recommendation are provided.

2. LITERATURE REVIEW

2.1 Irrigation Development in Ethiopia

Traditional irrigation is very old in Ethiopia (Awulachew et al., 2007). Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops in Awash Valley. Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal irrigation schemes in the late 1950s in the upper and lower Awash Valley. In the 1960s, irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley (Awulachew et al., 2007).

From 1974 to 1991, no large-scale private capital investment was committed as a result of the prohibition of private land ownership or rental of land on commercial scale by the land reform Proclamation of 1975 as per the socialist policy adopted by the Government. During this period public capital expenditure concentrated on the development of state farms and producer cooperatives which contributed for less than 10 percent of the total production during that period Consequently, commercial farm development during this regime was practically nonexistent. On the other hand, development of small scale irrigation was encouraged to be affected by the local farmers to cope with recurrent droughts (Fekadu et al., 2000).

Modern small-scale irrigation development and management started in the 1970s initiated by the Ministry of Agriculture in response to major droughts, which caused wide spread crop failures and food insecurity (Cherre, 2006).

Attempts have been made by the government to address the food security problems through preparation of relevant agricultural development policies and programs. However, low level of water use efficiencies is among the major constraints for development as well as operation of all water sectors including irrigation (Mezgebo et al., 2013).

2.1.1 Irrigation Water Control and Management

According to Salman et al (1999),"Water management" is defined as the planned development, distribution, and use of irrigation water in accordance with predetermined objectives and with respect to both quantity and quality of the water resources. It is the specific control of all human intervention on surface and subterranean water. Every planning activity that has something to do with water can be looked upon as water management in the broadest sense of the term.

There is no way that the cultivated area without a water management system can contribute significantly to the required increase in food production (Schultz and De Wrachien, 2002).

Almost all the irrigation schemes in Ethiopia have been functioning below anticipated targets (Habtamu, 1990). In spite of the considerable investment in irrigation development of both government and NGOs constructed and community managed irrigation schemes, the overall performance has remained far below expectations (Pariyar et al., 2016).

Haileslassie et al (2009), stated that irrigation development in the country did perform poorly because of lack of technology or technical deficiencies, but rather because of faulty assumptions and practices related to the operation and maintenance and overall management of the system. Given the complex set of constraints facing smallholder producers, providing access to irrigation water by itself is not enough; smallholders also require a broad range of support services (access to inputs, credit, output markets), knowledge of farming and secure land tenure (Kamara and McCornick, 2003).

According to Tulu (2003), analysis of existing situation indicates that if irrigation is to play a crucial role as engine for further expansion of agricultural production, the management and organization of irrigation systems, including their institutional implications, must be substantially improved.

2.1.2 Challenges of Irrigation in Ethiopia

According to Deneke and Gulti (2016), the main challenges for the development of irrigation in Ethiopia are listed hereunder. These challenges can be explained as technical constraints and knowledge gaps are identified:

- ❖ Inadequate awareness of irrigation water management as in irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities,
- ❖ Inadequate knowledge on improved and diversified irrigation agronomic practices,
- ❖ Shortage of basic technical knowledge on irrigation pumps, drip irrigation system, sprinkler irrigations, surface and spate irrigation methods
- ❖ Scheme based approach rather than area/catchments-based approach for the development of SSI Schemes,
- ❖ Inadequate baseline data and information on the development of water resources,
- ❖ Lack of experience in design, construction and supervision of quality irrigation projects,
- ❖ Low productivity of existing irrigation schemes,
- ❖ Inadequate community involvement and consultation in scheme planning, construction and implementation of irrigation development,
- ❖ Poor economic background of users for irrigation infrastructure development, to access irrigation technologies and agricultural inputs, where the price increment is not affordable to farmers.

2.2 Surface Irrigation methods

Water applications to crop fields are of various types. The most commonly used and most ancient type is surface irrigation methods (Land, 2002), through using gravity forces. This was used especially across river sides and it doesn't depend on mechanized equipment's. Nowadays, modernized irrigation systems are mostly used which works based on the pressurized energy system (Haddeland et al., 2006).

According to Welde and Gebremariam (2016), surface irrigation methods are furrow irrigation, flood irrigation basin irrigation and boarder irrigation. The choice and adoption of these irrigation methods are depending on the nature of the soil, the contour of the land, the head of the water stream, the quantity of water available and the nature of the crop.

It has been reported by Haddeland et al (2006), that 97.8% of irrigation in Ethiopia is done by surface methods of irrigation especially by furrow system in farmer's fields and majority of the commercial farms.

Furrow irrigation method is one of surface irrigation methods in which small regular channels direct water across the field. Furrow irrigation method is best suited to deep, moderately permeable soils with uniform flat or gentle slope of 0.1-0.5% for crops that are cultivated in rows such as vegetables, maize, cotton, tomato and potatoes etc (Ritzema et al., 1996). Furrows are particularly well adapted to irrigating crops, which are susceptible to fungal root rot since water ponding and contact with plant parts can be avoided, Nearly all row crops can be irrigated using furrow method rather than flooding (Willis, 2011).

Moderate to high application efficiency can be obtained if good water management practices are followed and the land is properly prepared. The initial capital investment is relatively low on lands not requiring extensive land forming as the furrow are constructed by common farm implements (Land, 2002). This irrigation method is best suited to medium and moderately fine textured soils with relatively high available water holding capacity and hydraulic conductivity, which allow significant water movement in both the horizontal and vertical directions. The method is also suited to fine textured soils on level sites, where it permits water impoundment (Willis, 2011).

2.3 Irrigation Technology Adoption

One important way to increase agricultural productivity is through the introduction of improved agricultural technologies and management systems (Doss, 2006). Technologies play an important role in economic development. According to Getahun (2012), the simplistic definition of adoption is basically the use of a technology.

Adoption and diffusion of technology are two interrelated concepts describing the decision to use or not to use and the spread of a given technology amongst economic units over a period of time. The rate of adoption is usually measured by the length of time required for a certain percentage of members of a system to adopt an innovation. Extent of adoption on the other hand is measured from the number of technologies being adopted and the number of producers adopting them (Bonabana-Wabbi, 2002).

Feder et al (1985), defined adoption as the degree of use of a new technology in a long-run equilibrium when a farmer has all of the information about the new technology and its potential. Therefore, adoption at the farm level describes the realization of a farmer's decision to implement a new technology. The "rate of adoption" is defined as the proportion of farmers who have adopted a new technology at a specific point in time (e.g., the percentage of farmers using motorized water pump). Furthermore, the "intensity of adoption" is defined as the level of adoption of a given technology, for example, by the number of hectares planted /irrigated with motorized pump improved.

Most farmers who adopt Water Lifting Technologies (WLTs) do so to irrigate in the dry season, which provides additional household income. Incidents and depth of poverty were found to be lower for households with access to irrigation (Gebregziabher, 2008). WLTs are usually used to grow marketable crops such as vegetables.

2.3.1 Factors Influencing Irrigation Technology Adoption

As of Adekoya and Tologbonse (2005), adoption of improved technologies is strongly affected by the policy environment like input supply, market, credit, price policies and improved supply system. Likewise, the effectiveness of extension service and other communication media as well as farmer's educational level influence the use of improved technology adoption.

According to Feder et al (1985), in their study of adoption innovation in developing countries, factors that influence technology adoption are credit, farm size, risk, labour availability and human capital and land tenure.

Legesse and Gashaw (2008), revealed that extension contact, poor distribution of inputs and technical assistance, socio psychological variables such as farmers' ability, belief, habit and customs, and expectations that affect the technology adoption.

The household head's age: farmers perception that technology development and the subsequent benefits, require a lot of time to realize, can reduce their interest in the new technology because of farmer's advanced age, and the possibility of not living long enough to enjoy it (Caswell et al., 2001; Khanna, 2001). Furthermore, elderly farmers often have different goals other than income maximization, in which case, they will not be expected to adopt an income enhancing technology. DiGennaro (2010), also found age to be positive and have a significant effect on the adoption of micro irrigation equipment.

Human capital is considered as one of the basic building blocks or means of achieving livelihood outcomes (Ellis and Mdoe, 2003). Human capital represents the skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives. At the household level human capital varies according to household size, educational level, skills and health status.

Danny et al (1997), indicates that technology complexity has a negative effect on adoption. However, education is thought to reduce the amount of complexity perceived in a technology thereby increasing a technology's adoption. Farmers who have invested in schooling and information will be better informed about the existence and general performance of different technologies, they will make more accurate assessments of differences in farm-level performance and will make more efficient adoption decisions (Asante, 2015). Zhou et al (2008), also found that educational level had a positive relationship with the adoption of water saving irrigation technologies in China.

Gender is an important determinant in technology adoption (Knowler and Bradshaw, 2007). The gender of the household head is hypothesized to impact the adoption decision but the effect could be either positive or negative. Traditionally, men and women play different roles when it comes to agricultural activities. Men are often the bread winners and are usually in control of finances and decisions regarding the purchases of agricultural technology and inputs. This social aspect may make men more likely to adopt new technology. Whilst women on the other hand are recognized to be more particular about the food requirements of the family (DiGennaro, 2010). Women may therefore be more likely to recognize the advantage of irrigation equipment for increasing household food security and be more likely to adopt irrigation technologies (DiGennaro, 2010).

Labour availability: some new technologies are relatively labour saving, and others are labour using. Feder et al (1985), labour availability may affect a farmer's decision to adopt technology. A labour shortage promotes the adoption of labour-saving practices, but hinders the implementation of technologies that require more labour input. Adeoti et al (2007), in the study of the adoption of treadle pumps in Ghana concluded that increase in labour availability had a positive effect on the adoption of the treadle pump technology since the technology required labour for operation.

Information is acquired through informal sources like the media, extension personnel, visits, meetings, and farm organizations and through formal education. It is important that this information be reliable, consistent and accurate. Thus, the right mix of information properties for a particular technology is needed for effectiveness in its impact on adoption. Information reduces the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time (Caswell et al., 2001).

Adeoti et al (2007), also found out that extension contact had a positive influence on the adoption of the treadle pump technology in Ghana. (Abdulai et al., 2005), on the study in china found that the involvement of extension services had a positive and significant impact on the adoption of water saving irrigation technologies for rice production. Understandably, farmers need to be aware of a technology in order to make use of it, especially associated with extension services. This implies that awareness is a contributing factor for adoption but not sufficient on its own.

As may be expected, access to fuel was found to be an important factor in the adoption of motorized pumps. Most motor pumps are imported by private companies, not through public support programs. Despite the involvement of private enterprises, there are insufficient spare parts and support services for adequate maintenance. The farmers reported that machinery frequently breaks down, and their unfamiliarity with the technologies leads to delays in agricultural activities and contributes to dissatisfaction with WLTs (Tadesse et al., 2008).

2.4 Emerging competition and conflicts over water

Water is a renewable resource, the available evidence indicates that Africa's freshwater resources are finite (Conley, 1995). Water is also extraordinarily vulnerable to human activities (Arnell, 2004). It is almost impossible to define the ownership of water and water is now universally recognized as a common good that should not be privately owned; instead, governments should act as custodians of their national water resources (Asmal, 1998).

The availability of adequate water supplies is critical to the national prosperity of a country since water is inextricably woven into irrigation and food production processes as well as into the provision of energy and, occasionally, transportation systems (Smith and AI-Rawahy, 1990; Van Wyk, 1998). The growing realization of water's strategic importance has fuelled most of the water resource development activities in Africa during the last century, including attempts to trap or impound water, so as to provide assured supplies during drier seasons when water is not easily available, or to transfer water from areas of ample supply to areas where water is in short supply (Ashton, 2002; Turton et al., 2006).

Unregulated and uncoordinated use of motor pumps is threatening the sustainable use and management of shared water resources. Motor pump users have become concerned with the increasing competition for water use, limiting the duration of water availability and creating water shortages (Zemadim et al., 2014).

Pump-based individualistic irrigation practices based on rivers and streams, without effective institutional arrangements and collective action for managing the shared resource, has counterproductive implications. The rapid expansion of pump irrigation is leading to increasing competition and conflict over the limited water resource (Dessalegn and Merrey, 2015).

Inequitable access to water and differential water use and benefits are often sources of conflicts over water. Conflicts may arise out of competition for scarce water and disagreements over its use. Such conflicts need to be managed for sustainable water use. Natural resource management involves competing interests; it is a form of conflict management (Yasmi et al., 2006). Elinor Ostrom argues that irrigation systems are among the most important forms of common-pool resources; they require conflict resolution mechanisms to resolve conflicts among users (Ostrom, 1991; Sabatier, 1992; Wunder, 2001). Appropriate institutional arrangements are essential to facilitate and coordinate collective action and cooperation required for successful irrigation.

The expansion of motor pump use has been without cooperation and coordination arrangements to facilitate shared use of water resources for irrigation. This is creating inequitable use of water among users of shared rivers, particularly affecting traditional schemes.

2.5 Land use/cover changes and expansion of Irrigation

Land cover refers to the physical materials on the surface of a given parcel of land, while land use refers to the human activities that takes place on or make use of land e.g. residential, commercial, industrial, agriculture, grazing, etc. Gupta et al (2012), described urban landscape as land use that is perceived as a way by which human beings utilize land while land cover exists as a natural environmental system.

Land use and land cover change (LULCC) is commonly grouped in to two broad categories: conversion and modification (Nigatu, 2014). Conversion refers to a change from one cover or use category to another (e.g. from forest to grassland). Modification, on the other hand, represents a change within one land use or land cover category (e.g. from rain fed cultivated area to irrigated cultivated area) due to changes in its physical or functional attributes.

In most developing countries like Ethiopia population growth has been a dominant cause of land use and land cover change than other forces. There is a significant statistical correlation between population growth and land cover conversion in most of African, Asian, and Latin American countries (Nigatu, 2014). Due to the increasing demands of food production, agricultural lands are expanding at the expense of natural vegetation and grasslands.

Land use change analysis is an important tool to assess global change at various spatial-temporal scales (Lambin, 1999). Land use is affected by economic, cultural, political, and historical and land-tenure factors at multiple scales. The increase in urbanization and anthropogenic activities have put an increasing demand on the limited land and soil resources for agriculture, forest, pasture, settlement and increasing industrial land uses. Mark and Kudakwashe (2010), in a study in Shurugwi district in Midlands Province of Zimbabwe observed the increase in cropland.

2.6 Application of Remote sensing, ERDAS and GIS

Application of remote sensing and GIS data made possible to study the changes in land use and land cover of selected areas (expansion of irrigation or irrigated land) and it consumes less time and cost providing better accuracy (Sharma, 2017). Satellite images, ERDAS and Arc GIS provide methods for analysis of land use changes and helps for proper land use planning and modeling. ERDAS and GIS provides a flexible environment for collecting, storing, displaying and analyzing digital data necessary for change detection (Shirazi, 2012). Remote sensing imagery is the most important data resources of ERDAS and GIS. Accurate land cover change information is necessary for understanding main factors, causes and environmental consequences of such changes. Evaluating land use/land Cover Change Dynamics in Bhimtal Lake Catchment Area (Malik and Panwar, 2017) and Evaluating land use land cover change on east of lake Tana (Gashaw and Fentahun, 2014) are some of the studies conducted using satellite images, ERDAS and Arc GIS techniques. Recently, remote sensing has been used in combination with Geographical Information Systems and Global Positioning Systems to assess land cover change more effectively than by remote sensing data only (Weng, 2002).

2.6.1 Image Classification techniques

There are two approaches to extract spectral informaton: the supervised and unsupervised classification (Richards and Richards, 1999). One should also consider a third approach, which is a “hybrid” supervised/unsupervised strategy that aspires to extract the attributes of both methods.

Supervised classification: this method involves selection of areas in the image, which statistically characterize the categories of interest.The supervised approach requires prior knowledge about the area, wich can be derived from fieldwork or from reference data on the area. Information about the area has to be supplied by the user through training samples and the number of classes has to be defined as well (Salem, 1995) .

Unsupervised classification: by this method, image pixels are assigned to spectral classes without the user having previous knowledge about the study area. Applying clustering methods, i.e. procedures to determine the spectral class of each pixel, usually performs it.

2.7 Estimation of water requirement and CROPWAT Model

CROPWAT model is a software program for the computation of crop water demand and irrigation programming. Moreover, the software provides for planning and management of irrigation schemes, developed based on the FAO Penman-Monteith method (Allen et al., 1998) .

Its basic function includes the calculation of reference evapotranspiration, crop water requirement and crop and scheme irrigation requirement. Calculation of water and irrigation requirements utilizes input of climatic, crop and rainfall data. The climatic input data required are reference evapotranspiration (monthly/decade) and rainfall (monthly, decade/daily). The crop parameters used for estimation of the crop evapotranspiration, water balance calculations, and yield reduction due to stress include; crop coefficient, Kc, length of growing season, critical depletion level, p, and yield response factor, Ky. Once all the data is entered, CROPWAT 8.0 Windows automatically calculates the results as tables or plotted in graphs. The time step of the results can be any convenient time step: daily, weekly, decade or monthly.

The program is sub divided into in eight distinct modules, five of which are for data entry and three for computations. The entry to the modules is through menu in the tool bar or alternatively using the navigation bar at the left-hand side of the main view (Allen et al., 1998). The data entry modules include climate/ETo, rain, crop type (dry crop), soil and crop pattern. The computation modules are CWR, schedules and scheme, for the calculation of crop water requirement, irrigation schedule and scheme supply, respectively (Allen et al., 1998).

2.7.1 Crop Water Requirement (CWR)

Crops need a continuously and right amount of water from the time of sowing to maturity. The rate of use of water is not the same for all crops. The rate of use of water varies with the kind of crop grown, time taken by the crop to mature, and the weather conditions like, temperature, wind and relative humidity (Tan and Fulton, 1980).

Water requirement of crop is the total amount of the water required to sustain the normal growth of plant. This includes the amount of water required to meet; losses through evaporation, losses through transpiration, application losses and special needs

(Sahasrabudhe and Sahasrabudhe, 1970). The term crop water requirement is defined as the "amount of water required to compensate the evapotranspiration loss from the cropped field" (Allen et al., 1998).

Bebremedhin and Peden (2004), cited by Adeniran et al (2010), reported that knowing seasonal crop water requirements is crucial for planning crop planting mixture especially during drought years. The growth and yield of any crop is related to the amount of water used. The variable amount of water contained in a soil and its energy state are important factors affecting growth of plants (Ciric et al., 2012). The accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapotranspiration (Nuha and Henery, 2000).

2.7.2 Irrigation Scheduling

Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper scheduling is essential for the efficient use of water, energy and other production inputs, such as fertilizer. It allows irrigations to be coordinated with other farming activities including cultivation and chemical applications. Among the benefits of proper irrigation scheduling is: improved crop yield and/or quality, water and energy conservation, and lower production costs (James, 1988).

Smith (2000), explained that when surface irrigation methods are used, however, it is not very practical to vary the irrigation depth and frequency too much. In surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all the time. Therefore, it is often sufficient to estimate the irrigation schedule and to fix the most suitable depth and interval: to keep the irrigation depth and the interval constant over the growing season.

2.7.3 Field Application Efficiency (Ea)

When water is diverted into any water application system, part of the water infiltrates into the soil for consumptive use by the crop, while the rest is lost as deep percolation and runoff. The efficiency terms determine these components and compare them with the volume of water actually applied to the field. The term is an indication of the effectiveness of the system in reducing losses during an irrigation event.

Field application efficiency (Ea) was developed to measure and focus attention upon the efficiency with which water delivered was being stored within the root zone of the soil, where it could be used by plants (Hansen et al., 1980).

According to Danny et al (1997), methods of determining application efficiency of a specific irrigation system is generally time consuming and often difficult because it may vary in time due to changing soil, crop and climatic condition.

Akenten (2013), explained and defined the situation of application efficiency with time and event specific, the first irrigation event using furrow irrigation can have a very low application efficiency if the length of run is long, furrows are freshly corrugated, stream size is wrong or for several other reasons. If irrigations are too close together, or the amount of water applied is too high, the application efficiency will be lower than it could be. This will indicate low irrigation efficiency, showing that water is being wasted as deep percolation. According to him, the purpose of application efficiency was to help estimate the gross irrigation requirement once the net irrigation need was determined and vice versa.

Application efficiency does not show if the crop has been under-irrigated. However, according to Danny et al (1997), it is possible to have high application efficiency and 50-90% can be used for general system type comparison. Smith (2000), reported that the attainable application efficiency according to the US (SCS) ranges from 55%-70%.

Akenten (2013), suggested that it could be in the range of 50-80%. According to Willis (2011), water application efficiency decreases as the amount of water applied during each irrigation increase. Furrow irrigation efficiencies vary from 45-60% (Teklu, 2016).

Smith (2000), suggested 60% attainable water application efficiencies for surface irrigation system. Also, Norman (1999), said that a minimum value of the ratio of crop water demand to the actual amount of water supplied to the field of 0.6 (or irrigation efficiency of 60%) is included in the design of most surface irrigation systems to accommodate crop water needs and anticipated losses. Value below this limit would normally be considered unacceptable.

2.8 Previous studies in Ethiopia on expansion of agricultural land

Many researchers have conducted land use and land cover change at different parts of Ethiopia. Most of these studies indicated that croplands have expanded at the expanse of natural vegetation including forests and shrub lands (Flugel, 1995; Kahsay, 2004). Kahsay (2004), in his study, in southern Wollo, reported the decline of natural forests and grazing lands due to conversions to croplands.

Hadgu (2013), identified that decrease of natural vegetation and expansion of agricultural land over a period of 41 years in Tigray, northern part of Ethiopia. He concluded that population pressure was an important deriver for expansion and intensification of agricultural land in recent periods.

Kindu et al (2013), investigated a significantly reduction of natural forest cover and grasslands, but an increase of croplands between 1973 and 2012 in Munessa, Shashemene landscape of the Ethiopian Highlands. Zeleke and Hurni (2001), reported an expansion of cultivated land at the expense of natural forest cover between 1957 and 1982 in Dembecha area, north-western Ethiopia.

Yeshaneh et al (2013), also showed a significant decrease of natural woody vegetation of the Koga catchment since 1950 due to deforestation in spite of an increasing trend in eucalyptus tree plantations after the 1980's. Bewket and Abebe (2005), reported a reduction of natural vegetation cover, but an expansion of open grassland, cultivated areas and settlements in Gish Abay watershed, north-western Ethiopia.

It was also reported by Geremew (2013), that land use and land cover changes affected the stream flow of Gilgel Abay watershed, Ethiopia. His study identified that there was an increase of stream flow by 16.26 m^3/s during wet months and decreased by 5.41 m^3/s from 1986 to 2001 as a consequence of conversion of cultivated land.

In Lake Tana basin there is expansion of agricultural land at the expense of forest, shrubs and wetland. Many researchers have conducted land use and land cover change at different catchments in the country and in Amhara regions and in sub basins of the Abay and Tana. But studies on small-holder farmer-based irrigations are not sufficiently done, particularly such studies on the catchments of Gumara River are absent. Therefore, assessment of the management and expansion of smallholder pump irrigation schemes in the lower Gumara River reach is the research gap.

3. MATERIALS AND METHODS

3.1 Study Area and Data Availability

3.1.1 Location

The study area is the downstream reach of Gumara River and is located to the east direction of Lake Tana; it is found between latitude of 11^{0}47’24.49” -11^{0}54’31.41” N and longitude of 37^{0}40’09.24” - 37^{0}29’17.07” E with elevation range between 1788 to 1805m. The total area of this study is 30.4207 square kilometres (Figure 3-1). It is located in Lake Tana Basin, Amhara Regional State (South Gondar) near Lake Tana.

Lake Tana is fed nearly by 60 water sources. However, four main perennial rivers namely: Gilgel Abay, Gumara, Rib, and Megech contribute 93% of the inflow (Kebede et al., 2006). Gumara River originates from the high Mountainous area south and east of the town Debre Tabor at an approximately 3050 meter above sea level. Gumara River is one of the tributary rivers of Lake Tana. The river flows westwards for a length of 132.5 km until it reaches Lake Tana. The Gumara watershed is located in four woredas, Fogera, Dera, Farta and Esite which are under the administration of Debub Gondar Zone of Amhara Regional State in Ethiopia (Abate et al., 2015).

This assessment is to be undertaken on Gumara River, specifically lower Gumara smallholder motor pump irrigation schemes located in Fogera and Dera Woredas. Specifically, the reach of the River considered for this study is at a distance of 23.4km below the Wanzaye Spring until the river joins Lake Tana and the area covering 300 m left and right of this reach. This is roughly the assumed area under small-holder motorized irrigation that uses Gumara River (based on field observations and information of the local irrigators).

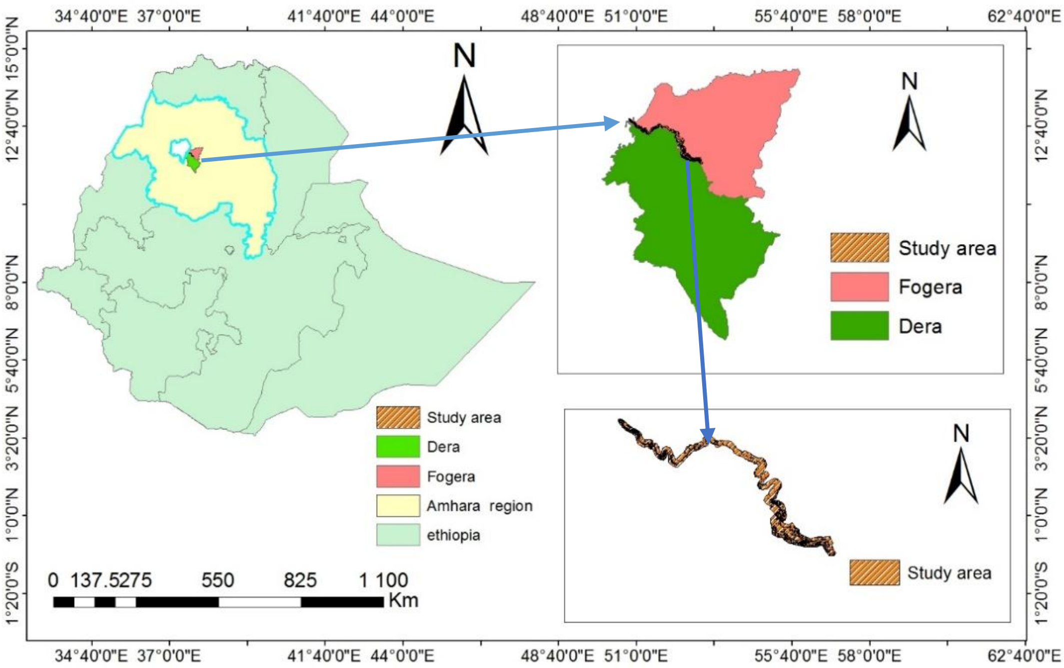


Figure 3-1 Location map of the study areas

3.1.2 Topography

Gumara watershed consists of rugged and undulating topographies which vary from 1790 m *asl* up to 3700 m *asl*. The area has a steep slope (greater than 25%) in the high mountainous region in the east which rises above 2000 m asl (above sea level) elevation, and of lower slope (below 3%) towards Lake Tana, the area that ranges from 1700 - 1900 m *asl* altitude. The lower down plain reaches, near the confluence of Gumara with Lake Tana, is subject to inundation in wet seasons. This is because of the flat slopes, further worsened by back water effects of the Lake which is at higher levels during the flood (Abate et al., 2015).

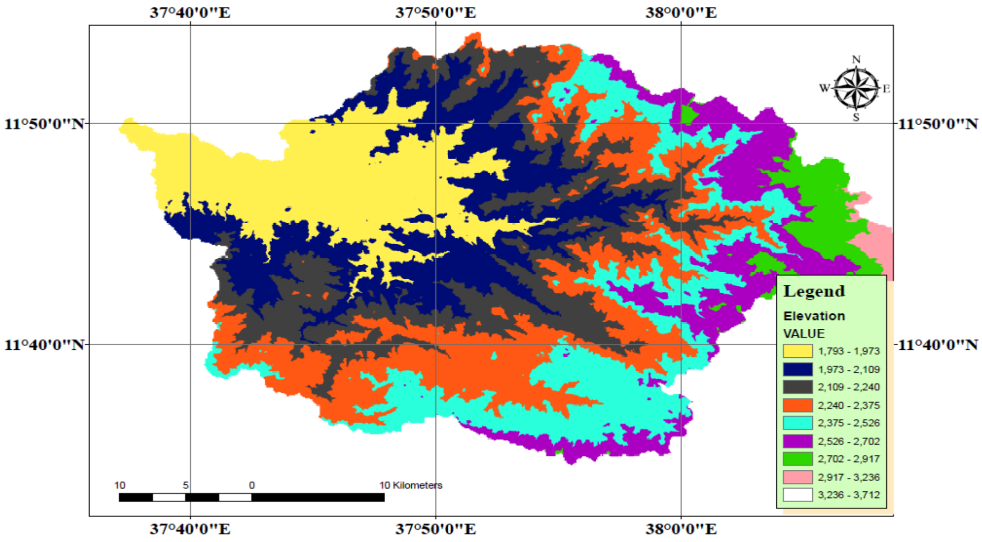


Figure 3-2 Topography of Gumara Watershed

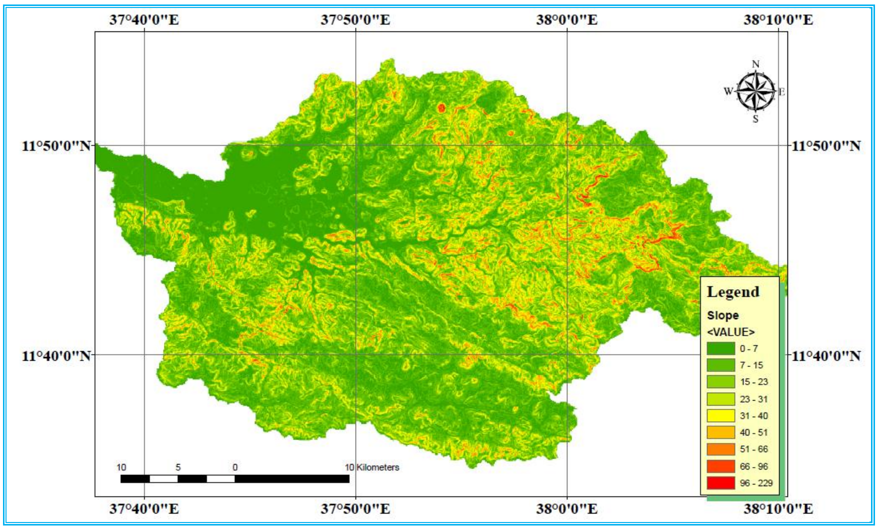


Figure 3-3 Slope of Gumara Watershed

3.1.3 Climatic conditions

3.1.3.1 Rainfall

The annual Rainfall is relatively higher in the watershed ranging between 1145 mm up to 1523 mm; the western plain having lower rainfall, 1145-1300 mm/yr, and the mountainous areas having higher rainfall, greater than 1300 mm/yr (Abate et al., 2015).

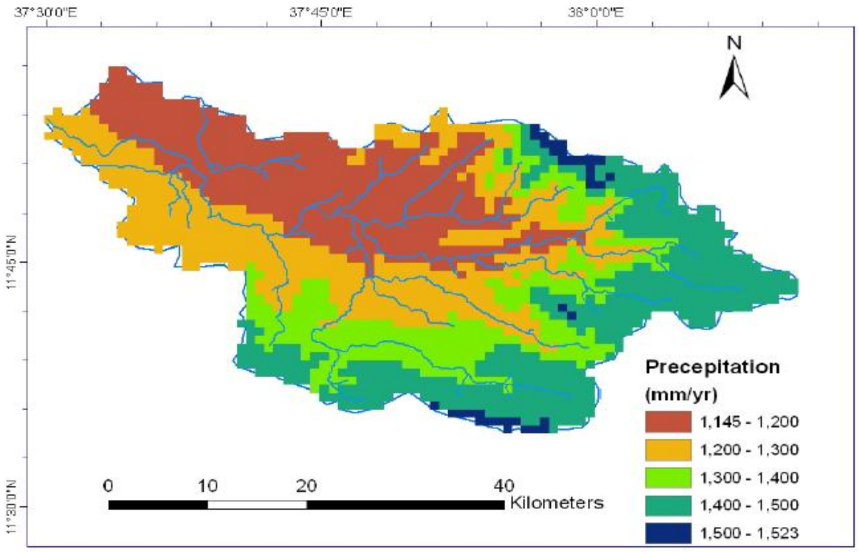


Figure 3-4 Rainfall distribution in Gumara Watershed

3.1.3.2 Temperature

The maximum and minimum monthly temperature in the watershed varies between 23^{0}C-29.9^{0}C and 7^{0}C-14^{0}C respectively. Annual maximum and minimum temperature vary between 16^{0}C-27^{0}C and 2^{0}C-12^{0}C (Abate et al., 2015).

3.1.4 Land use/cover system

The land use practice in the watershed as shown in the table below is dominated by cultivated land and followed by Grass land (Abate et al., 2015).

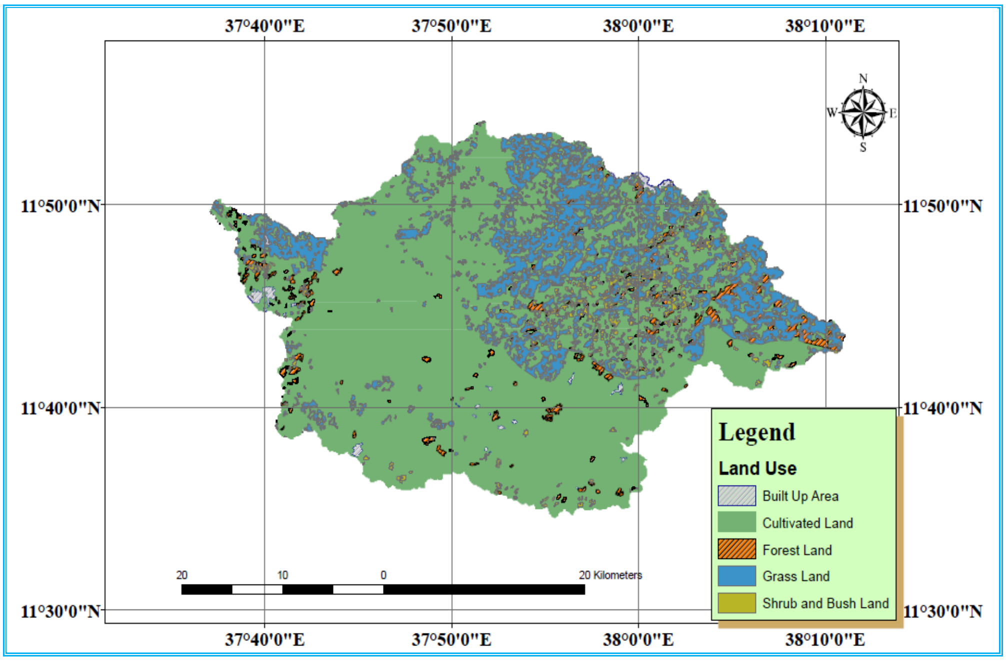


Figure 3-5 Land use in Gumara Watershed

Table 3-1 percent of area coverage for land use in Gumara Watershed

Land use land covet type	Area cover (km^2)	Percentage of Area coverage
Built Up Area	9	0.70
Cultivated Land	986	76.97
Forest Land	35	2.73
Grass Land	220	17.17
Shrub and Bush Land	31	2.42

3.1.5 Soil characteristics

The major soil types in the Fogera woreda exhibit a general relationship with altitude and slopes. Vertisols and Fluvisols are generally dominating soil types in the woreda and especially the lowland flat plains, valley bottoms and river terraces. Texturally these soils are sandy clay and sandy loam respectively (Legesse and Gashaw, 2008).

In the Fogera plain soil is dominated by vertisol and clay texture (Bayuh Belay Abera, Marc Cotter, Kalimuthu Senthilkumar and Folkard Asch).

The major soil types in Gumara exhibits a general relationship with altitude and slopes. Vertisols and Fluvisols are generally dominating the lowland flat plains, valley bottoms and river terraces. Texturally, these soils are heavy clay and sandy loam, respectively. Vertisols are characterized by their high content of expanding smectite clay minerals (Krystyna Stave* Goraw Goshu Shimelis Aynalem).

According to the Woreda Office of Agriculture, the dominant soil type in the Fogera plains is black clay soil (ferric vertisols), while the med and high-altitude areas are orthic Luvisols (Figure 3-6) (Fogera Woreda Pilot Learning Site Diagnosis and Program Design, January 2005).

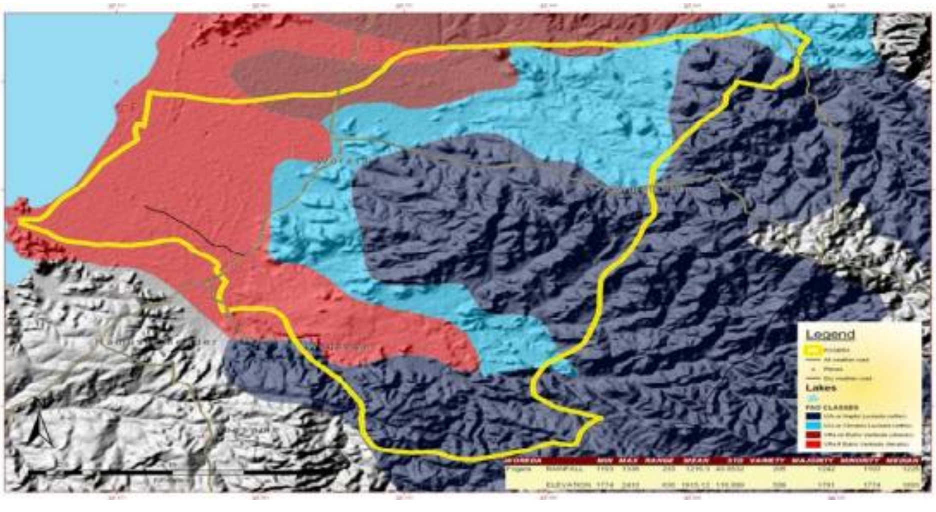


Figure 3-6 Soil types in Fogera woreda

3.1.6 Data Availability and source

For this study, daily meteorological data, river discharge data and Satellite image were collected. Daily meteorological data such as rainfall, minimum and maximum temperature, relative humidity, sunshine and wind speed and river discharge data were collected from National Meteorological Agency and Abay Basin Authority in Bahir Dar branch respectively.

Table 3-2 Data availability and source

Data type	Source
Metrological data	Ethiopian Metrological Agency, Bahir Dar branch
Stream flow data	Abay Basin Authority, Bahir Dar branch
Satellite image	Download from
-Landsat 5 TM 2001	http://earthexplorer.usgs.gov/
-Landsat 5 TM 2010	
-Landsat 8 TM 2017	
Grid coordinates	Surveying using GPS
Number of users kebeles	Fogera and Dera Woreda Agricultural Office
Households of user kebeles	Kebeles DAs
Type of crop grown and Irrigation practices	Observation and interview

3.2 Conceptual Framework of the Study

The overall study of this research, methods and expected output is described by conceptual framework (Figure 3-7). This framework generally shows type of data that collected, method of collection, methods that follow to analyse, models used and expected output. Generally, contain data, process and results.

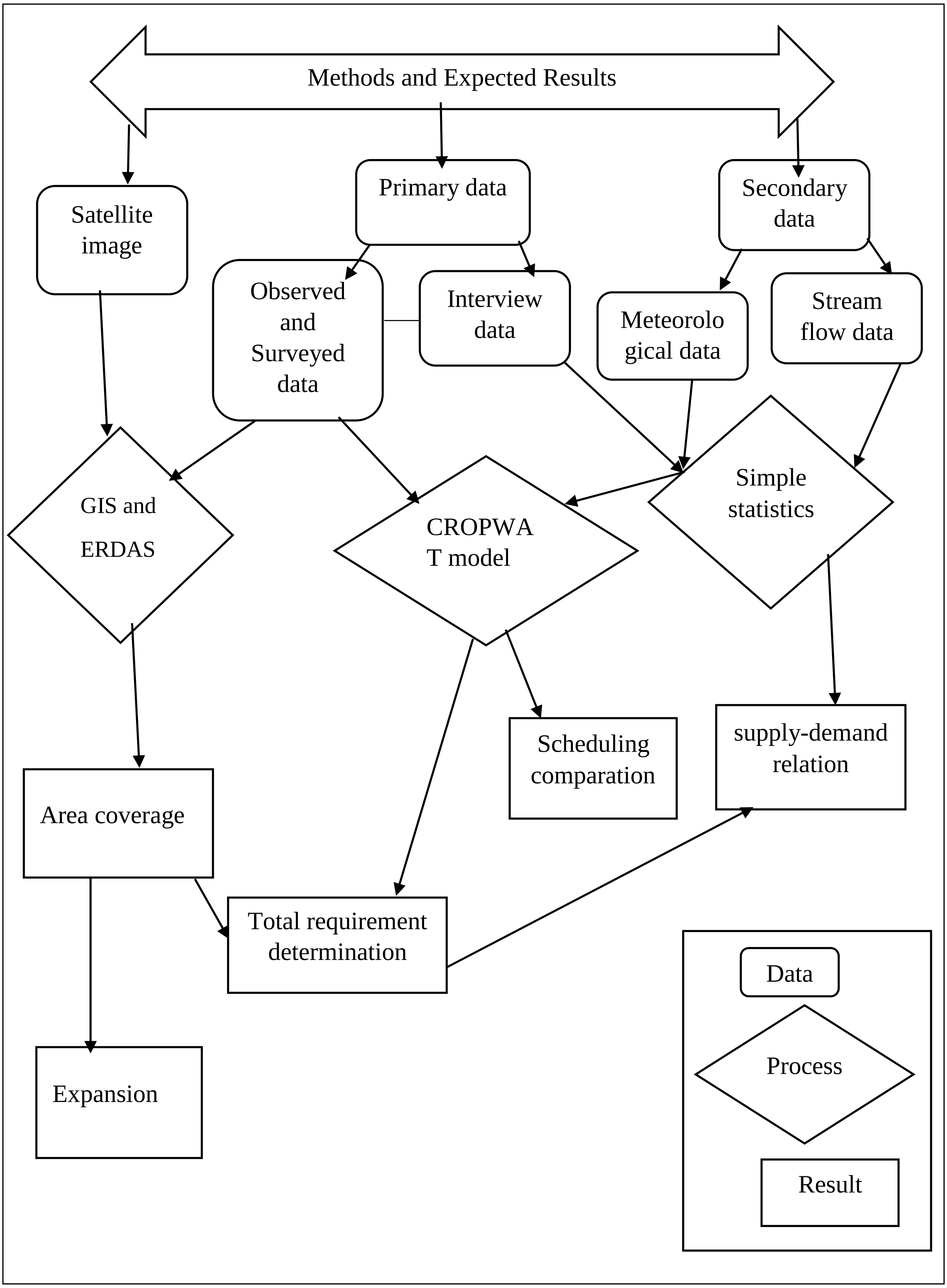


Figure 3-7 Conceptual Framework of the Study

3.3 Data Collection Methods

Both primary and secondary data were used for this study to obtain quantitative and qualitative information. The research work included a review of the literature on assessment of the management and expansion of small holder motor pump irrigation schemes, formal and informal communication with respective organization, interview with the aid of questionnaires and observations, as well as the analysis of data that are obtained during field observation and collected from respective organization. The expansion of small-holder irrigation for the last 16 years (2001-2017) has been investigated.

3.3.1 Primary Data Collection Methods

In primary data collection, the data is collected using methods such as interviews and questionnaires. It is important to prepare a tabulation plan and there are cases when tables cannot be produced because questionnaires were designed without having a tabulation plan in place. The main methods of primary data collection include; Direct observation, Questionnaires, Interviews, and Case studies.

- **Direct observation and field survey**

Direct observation was used to directly observe the farming systems of the study area. It was an important method for the study to get acquainted with the present situation of the Study area. Through direct observation, information was obtained on topography, water sources, vegetation, infrastructure, land use, soils, crops, etc. This served mostly as a basis for discussions that followed with the farmers and key informants. Grid coordinates were collected using GPS for the purpose of preparing area of interest and for ground truth during image classification and other relevant data were surveyed at the field.

- **Questionnaires**

Questionnaires are a popular means of collecting data, but are difficult to design and often require many rewrites before an acceptable questionnaire is produced. For this case both open questions and closed questions were used.

- **Semi-structured interview**

Semi-structured interview was applied in two phases to collect different sets of data. In the first phase, semi-structured interview technique was employed to collect qualitative data using a checklist included randomly selected farmers and focused on general issues that were listed in the checklist. In the second phase, both qualitative and quantitative data were collected from motor pump user farmers. They were conducted at work, at home, at religious centre, in the street or in a shopping centres, or some other agreed location. As per farmers' interest the interview was scheduled mainly on holidays.

Generally, the interview took three forms;

- Interview with groups of farmers to obtain information on community interactions
- Interview with individual farmers to obtain representative information
- Interview with key informants to obtain expert knowledge.

3.3.2 Sample Size Determination

This study has used a random sampling method to select the farmers for the surveys. The sample has covered motor pump user farmers including; males and females on proportionate to size basis and research objectives. Frist, Kebeles that use motor pump for irrigation directly from Gumara River from the woreda and then the sample kebeles from these kebeles were chosen. For selection of the sampled adopter farmers two-stage random sampling strategies were adopted.

First stage: Motorized water pump user kebeles were purposely selected based on their number of irrigation users by water pump on the river directly, the number of hectares irrigated and based on their proximity for the easy of data collection. For this four kebeles (Bebeks, Shena, Wagetera and Gazen Aridafofot) from Fogera Woreda and two kebeles (Jigina and Geregera Gedam Eyesus) from Dera Woreda were selected (Table 3-3).

Table 3-3 Small holder motor pump irrigation user and sample kebeles

Woredas	Gumara river motor pump irrigation user kebeles	Sample kebeles used for this study
Fogera	Wagetera Kdste hana Shina Kuhar Mikael Bebeks Aba kiros Sendaga Aba Gunda Gura Amba Dilmo Dena Gazen Aridafofot	Wagetera Shina Bebeks Gazen Aridafofot
Dera	Mtslina Tana Zarina Jegina Geregera Gedam Eyesus	Zarina Jegina Geregera Gedam Eyesus
Total	12	6

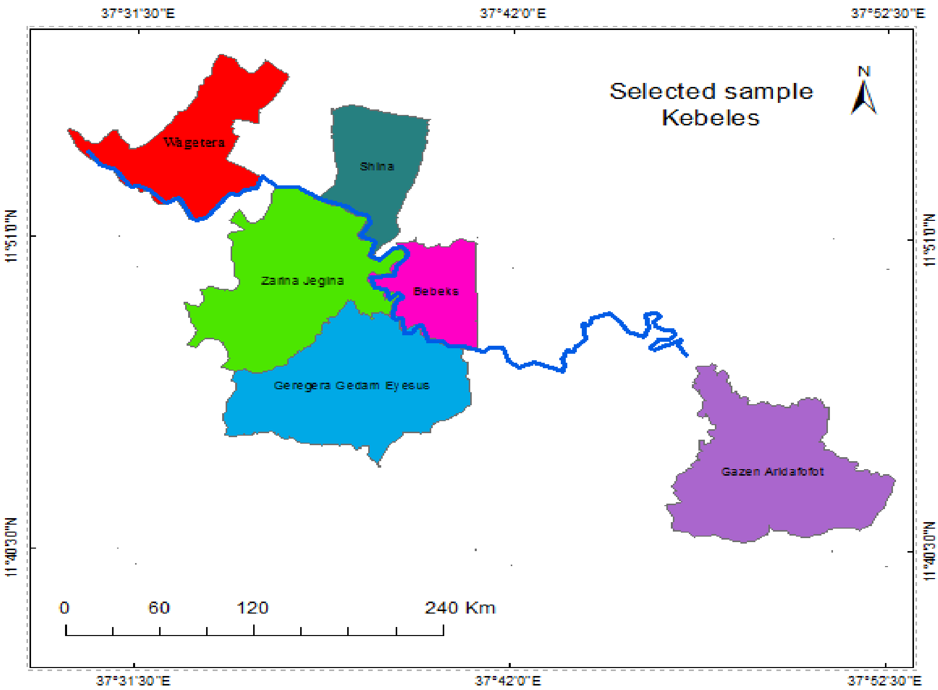


Figure 3-8 Selected sample kebeles

Second stage: After identifying the irrigated kebeles the respondents' farmers were selected from the motorized water pump user farmers randomly. The adopter farmers were identified by the kebele development agents and by the village leaders and based on their lists the respondents selected randomly for this study. It covers both female and male farmer household respondents.

Therefore, the sample size was selected depending on the number and distribution of motorized water pump users in each kebele using sample size determination formula. Then the selected farmers were interviewed.

As Yamane (1967) provides a simplified formula to calculate sample sizes, Singh and Masuku (2014), cited that:

$$n = \frac{N}{1+N(e)2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.1)}$$

Where: n=is the sample size = the number of required samples; N=is the population size= total households; e= is designed level of precision.

For this study the calculation has been carried out through using 95% confidence interval (α=5%), 10% precision level and 50% degree of variability (P=0.5). Therefore, in order to select the sample household, the research used equation (3.1).

The required sample households of each irrigation scheme or for each sampled kebeles (n) were, calculated using equation (3.2).

$$n1 = \frac{N1(n)}{\sum N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.2)}$$

There are 4848 motor pump user households for the selected six kebeles from these the total sample size determined by using sample size determination formula was interviewed 98 households with semi-structured questionnaire (Table 3-4).

Table 3-4 Sampling frame and the sample size

Kebeles	Motor pump user households		sample size	
	Males	Females	Males	Females
Jigina	1231	210	25	4
Bebeks	846	145	17	3
Shina	1218	67	25	1
Wagetera	601	70	12	1
Gazen Aridafofot	152	24	3	1
Geregera Gedam Eyesus	239	45	5	1
Total	4287	561	87	11
Sum total	4848		98	

3.3.3 Secondary Data Collection

Daily climatic data of minimum and maximum temperature, rain fall, relative humidity, wind speed and sunshine hours were collected from Bahir Dar meteorology branch office for the stations near flood plain from the period 2001 to 2017 and Gumara River stream flow data from Abay Basin Authority from the period 1980 to 2014 were collected. Additional secondary data were collected from kebeles Development Agent or DAs, Office of Agriculture, Reports and Research publications.

The ETo estimation for Gumara river small holder motor pump irrigation is dependent on Wanzaye and Bahir Dar meteorological stations data. The meteorological stations are taken as an option, because of their proximity. Wanzaye station which is the nearest has only the 3rd class climatic data, containing (RF and temperature) so Bahir Dar station which has the first class (RF, temperature relative humidity, wind speed, and sunshine hour) from them relative humidity, wind speed, and sunshine hour were used. The station names and data collected are listed in the (Table 3-5).

Table 3-5 Stations and type of data collected (x) from (2001-2017G.C)

Station	Coordinate of station		Type of data collected in the stations					
	X	Y	RF	Tmax	Tmin	RH	SS	WS
Wanzaye	356145	1303734	x	x	x			
Bahir Dar	324382	1280212				x	x	x

Where RF - rainfall, Tmax -maximum daily temperature, Tmin -minimum daily temperature, RH – Relative humidity, SS - sunshine hours and WS -wind speed.

3.3.4 Satellite images

Land use/land cover change studies for the last 16 years (2001-2017) have been conducted to evaluate the expansion of irrigation on the study area. Satellite images were obtained from http://earthexplorer.usgs.gov/, Land Sat 5TM and 8OLI sensors (Table 3-2). Then land use and cover classification has been done using GIS 10.1 and ERDAS Imagine2014 classification software.

3.4 Data Quality Analysis

The data was analyzed with reference to the purpose or objective of the study and analyses was done with the reference to the research problem. Therefore, in this study; the data generated through questionnaires, key informant interviews, formal and informal discussions were analysed and interpreted qualitatively and quantitatively. The quantitative data or information from close ended questions were first recorded and organized in a Microsoft Excel spreadsheet, the result was reported using tables and graphs. Simple descriptive statistical methods such as average and percentage were used. The qualitative data or information from open ended questions were analysed through systematically organizing the information and giving attention to local situations. Meteorological data and stream flow data were analyzed by using linear average method.

3.4.1 Climate data conversion

Climate data are, commonly, standardized by the National Meteorological Service Agencies. However, some conversions are required in order to adjust the data into the format accepted by CROPWAT 8.0 software.

Before using the record data for our purpose, it is necessary checking continuity and consistency of the data. The continuity of record may be brocken with missing data values due to different reasons like measuring instrument malfuctional and absence of observer etc. Accordingly, the data was checked for errors and the missing data, though very few, were filed from the average values.

3.4.2 Rainfall pattern

Precipitation is the major factor, which controls the hydrology of the area. Daily rainfall data was gathered for Wanzaye station to 16 years (2001-2017) as shown in Figure 3-9.

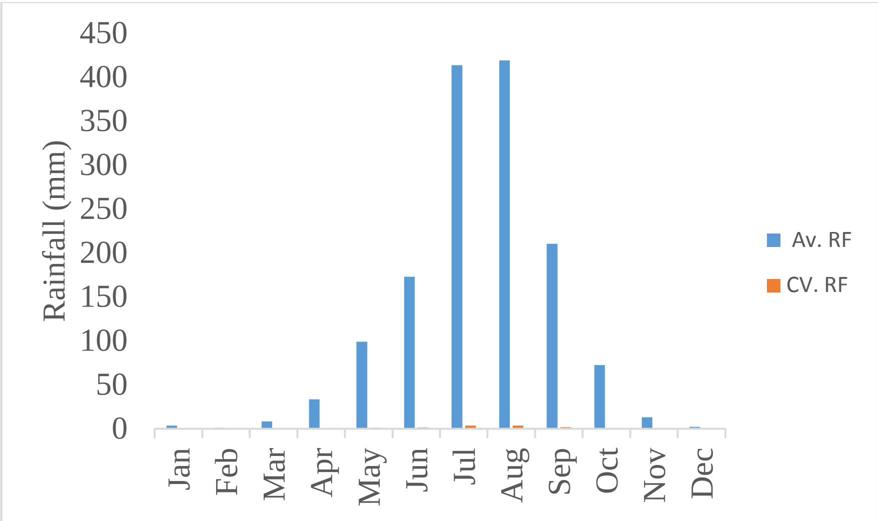


Figure 3-9 Mean monthly rainfall pattern of Wanzaye Station

The pattern of the seasonality of rainfall in the study area is determined by computing mean monthly rainfall ratio with that of rainfall module as rainfall coefficient according to (Gamachu, 1977), classification shown on Table 3-6.

Table 3-6 Rainfall Coefficient classification

Coefficient	Designation /Represent/
<0.6	Dry (represent a dry season/month)
≥ 0.6	Rainy (represent a rainy season/month)
0.6 to 0.9	Small Rains (represent small rain season/month)
≥ 1	Big rains
1.0 to 1.9	Moderate (represent big-rains with moderate concentration)
2 to 2.9	High (represent big-rains with high concentration)
3.0 and over	Very high (represent big-rains with very high concentration).

Rainfall coefficient is defined as the ratio of mean monthly rainfall to rainfall module (one-twelfth of the annual total) is shown on Table 3-7.

Table 3-7 Monthly average (2001-2017) Rainfall and Rainfall coefficients

Month	Av. RF	Cv. RF
Jan	3.6	0.03
Feb	1.1	0.009
Mar	8.2	0.07
Apr	33.5	0.28
May	98.8	0.82
Jun	172.9	1.43
Jul	413.5	3.43
Aug	419.1	3.47
Sep	210.5	1.74
Oct	72.3	0.6
Nov	13.1	0.11
Dec	2.1	0.02
Annual	1449	12

Accordingly, July to August big-rains with very high concentration, June and September big-rains with moderate concentration, May and October Small Rains, the rest (November, December, January, February, March and April) are known as dry months. Irrigation is required if crop production is predicted in the dry months of the year.

3.4.3 Temperature, wind speed, relative humidity and sunshine hours

Optimum temperature plays an important role on the growth period and the production of crops. The mean minimum and maximum temperature at Wanzaye station is 13.25 and 28.5^{0}C, respectively. The monthly mean minimum temperature varied from 10.1^{0}C in December to 15.2^{0}C in May and the monthly mean maximum temperature varied from 24.7^{0}C (August) to 31.9^{0}C (April). Wind speed, sunshine hours' duration and relative humidity of Bahir Dar station was used. All climatic conditions are shown on Appendix Table 2-2.

3.4.4 Stream flow condition

Hydrological data that is discharge (stream flow) data of the Gumara River was collected for the year 1980 up to 2014 from Abay Basin Authority in Bahir Dar branch office. The mean monthly discharge data of 1980-2014 for Gumara River used for the analysis of demand and supply of irrigation activities following the river course are shown on Table 3-8.

Table 3-8 Monthly Average Gumara flow in m^3/sec

Month	Gumara average stream flow
Jan	3.5
Feb	2.3
Mar	2.0
Apr	1.8
May	3.2
Jun	15.5
Jul	93.3
Aug	157.6
Sep	96.4
Oct	33.8
Nov	12.0
Dec	6.8

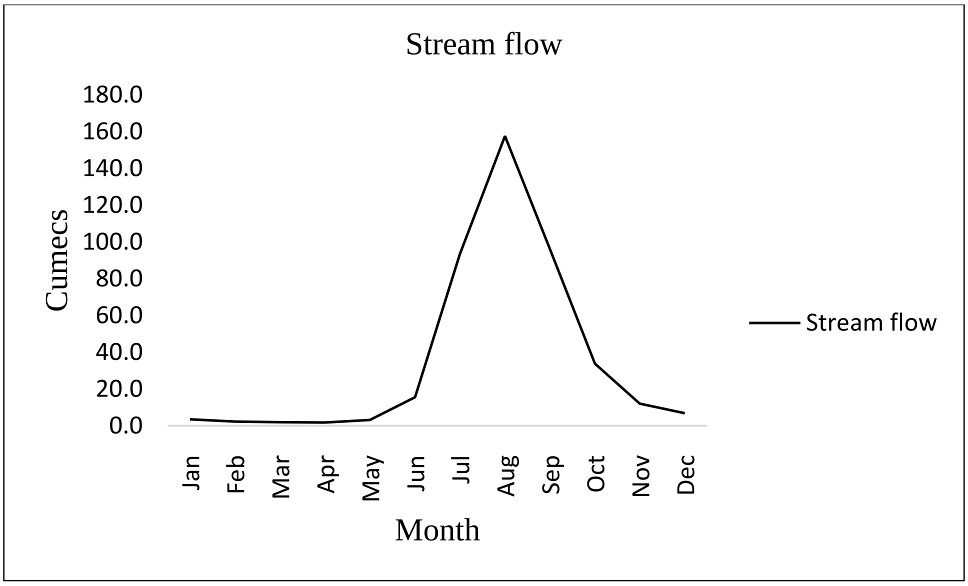


Figure 3-10 Gumara stream flow

3.5 Existing crop production and management of the area

3.5.1 Types of crops grown

Crop production remains the main stay of farmers in the study area. Farm households depend mainly on crops both for food and cash income. The area is dominantly covered by cereals and horticultural crops. Maize, Rice, Teff, and Barley, among cereals; Onion, Potato, Tomato, Cabbage and Hot Pepper among annual horticultural crops are commonly grown in the area (from interview and field observation).

3.5.2 Cropping pattern

Cropping pattern is the system by which farmers' grow crops in a particular sequence, mixture or rotation. Among several cropping systems, farmers in the study areas mainly practice crop rotation. The most common crop rotations are horticultural-cereal-cereal and cereal-cereal-cereal. The horticultural-cereal-cereal approach is the most widely practiced. This might be because cereals and horticultural crops are the major food crops for the community. The most common crops that rotate across the surveyed areas are Onion/Tomato/Potato/Cabbage/-Maize-Rice-Teff. Some farmers at the surveyed areas practice residual moisture cropping by using residual moisture. The most common residual moisture cropping in these areas is: Rice-Teff/Barley up to the season October (from interview and field observation).

3.5.3 Crop calendar

A crop calendar is very important in understanding the farming system as it shows the priorities of the farmers in allocating their limited resources. shows the schedule for the operations starting from land preparation to harvesting and threshing.

3.5.3.1 Land preparation and planting

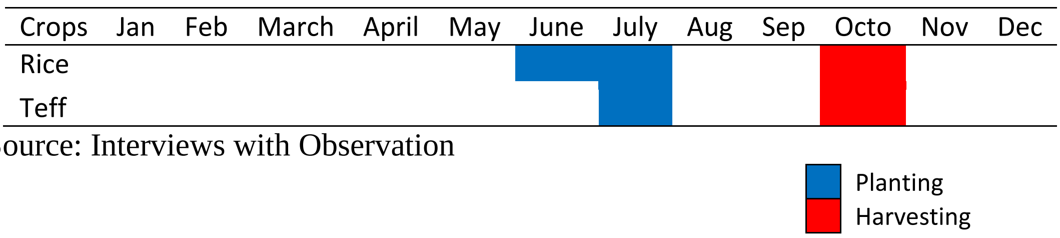
Priority in land preparation is given to cereals (maize, rice, teff and barley) and horticultural crops (onion, tomato, potato, cabbage and pepper). Less priority is given to pulses and oil crops. Land preparation starts right after harvesting crops of the previous season. Depending on the precursor crop and the degree of weed infestation of the fields, for most crops the number of ploughings significantly varies, which ranges from 2 to 5 until the seedbed becomes fine and ready for planting.

3.5.3.2 Cropping seasons

Three types of cropping seasons are known in the study area, namely main season (rain fed agriculture), wet season with supplementary irrigation (residual moisture) and full irrigation in the dry season.

Main season cropping: The main cropping season is the most dominant system in the study area, when crops are entirely grown under rain fed condition. Rice and Teff are the most important crops grown in the main season. The cropping operation (from land preparation to harvesting/threshing) is accomplished from Maye/June and ends by October of the next year.

Table 3-9 Planting and harvesting times for main season crops



Source: Interviews with Observation

Residual moisture cropping: The wet season irrigated cropping is the crop which is planted with residual moisture in September. The residual moisture cropping system is mainly practiced more in Fogera. The most common crops grown are teff and barley.

Dry season cropping: Irrigation during the dry season starts with land preparation soon after harvesting the crops grown on residual moisture in September. From planting to harvesting it accomplished from November to June. Maize and vegetables (tomato, potato, onion and cabbage) are planted with irrigation water during the season.

3.5.3.3 Selected crops for model input

Selected dry season crops for the model input are; Onion, Tomato, Potato and Maize. The selection criteria are that from the survey and interview, this are the main dominant crops in the study area.

Table 3-10 Planting and harvesting times for dry season crops

Crops	Jan	Feb	March	April	May	June	July	Aug	Sep	Octo	Nov	Dec
Onion		Harvesting									Planting	
Tomato			Harvesting								Planting	
Potato			Harvesting								Planting	
Maize			Planting			Harvesting						

Source: Observation with Interviews

Planting
Harvesting

3.6 Image processing for land cover change

Landsat satellite imageries were used in the study to identify changes in land cover distribution. For land cover mapping of the study area, three satellite images were applied to represent the land cover condition of the years 2001, 2010 and 2017. Landsat 5 satellite images were used for the years 2001 and 2010 and Landsat 8 for the year 2017 for classification.

Landsat is one of the various satellites used to gather data for images of the Earth's land surface. These satellites are equipped with sensors that respond to Earth-reflected sunlight and infrared radiation. Land sat imagery of the study area follows a path 170 and row 052 captured from January to March. The image is particularly taken in dry season because of indicating dry season vegetation, this gives an advantage to reduce confusion of wet and dry cropping. Land sat Images of 2001, 2010 and 2017 were downloaded from a website: http://earthexplorer.usgs.gov. The acquisition dates, sensor instrument, path /Row and Resolution of the image are shown on Table 3-11.

Table 3-11 Sensor, Satellite name, path/row, acquisition date and resolution

Sensor instrument	Satellite Name	Path	Row	Date of acquisition	Spatial resolution (m)
Landsat TM	Landsat_5	170	52	March 01, 2001	30
Landsat TM	Landsat_5	170	52	Jan 21, 2010	30
OLI/TIRS	Landsat_8	170	52	Jan 24, 2017	30

3.7 Image classification

ERDAS IMAGNE2014 image classification tool was used to prepare land cover map of 2001, 2010 and 2017. In this study land cover according to specified class was estimated using the supervised image classification in ERDAS IMAGNE2014 software. For the supervised image classification, knowledge of the area and information collected during field work are important inputs. Supporting information was also gathered from local elder people and field survey. The sample set was created using the band combination of 3, 2, 1 for 2001, 2010 and 4, 3, 2 for 2017 image for visual interpretation of the image in their true color.

Generally, a total of four major land cover classes were selected in this study this are Irrigated Agricultural land: which areas used for crop cultivation, Non-irrigated Agricultural land: which areas of bare lands that have little grass, Forest/shrubs land: which land covered include ever green forest land, natural forest, plantation forest and areas with shrubs, bushes and small trees and Flooded agricultural land: It refers the area cached by flood, logged and swampy water, the river itself and ponds around the area.

3.7.1 GPS data (GCP)

The motor pump irrigation scheme is analysed for a coverage of 200-300m laterally from right and left of the river bank starting from Wanzaye town up to Lake Tana. This reach is approximately 23.4km distance longitudinally. Ground truth data was collected during the field work period using GPS, for the delineation of area of interest (AoI) and for the ground truth verification. Part of the data is shown in the Appendix Table 2-14.

3.7.2 Accuracy of image classification

Accuracy assessment is necessary for image classification process. Classification accuracy could be affected by resolutions of images used and the need to generalize and so on. As a result, errors are always expected. To assure wise use of land cover maps and accompanying statistics derived from remote sensing analysis, the errors must be quantitatively explained by GCP.

Confusion or error matrix is the base for accuracy assessment. The matrix gives a cross tabulation of the class label predicted against the ground truth GPS data. The confusion matrix gives a vital information on image classification and also relatively easy to use and interpret to both map user and producer community.

The overall accuracy from confusion matrix is the total number of correctly classified pixels divided by the sum of ground truth pixel, users and producer accuracy measure the correctness of each category with respect to errors of commission and omission. The producer accuracy is the number of corrected divided to the references (GCPs) that taken. The user accuracy is the number of corrected divided to the total number of classified in the error matrix.

Kappa check is a type of technique used in accuracy assessment. It expresses the agreement between two categorical data sets. Kappa value lies between -1 and 1, where -1 represents no agreement at all meanwhile 1 indicates a perfect agreement. Generally maximum likelihood estimates of Kappa were computed as follows;

$$K = \frac{(po-pc)}{(1-pc)} \quad \text{...} \quad (3.3)$$

Where: - Po=the proportion of the observed agreement

Pc=the proportion of agreements expected by chance

Monserud and Leemans (1992), suggested that use of statistics Kappa value as <40% is poor, 40-55% fair, 55-70% good, 70-85% very good and greater than 85% as excellent.

3.8 CROPWAT Model

The computer program available in (Allen et al., 1998), FAO Irrigation and Drainage Paper "CROPWAT" has been used for the calculation of crop water requirement. This program is based on Penman-Monteith approach and procedures for calculation of crop water requirements. Crop water requirement of each crop was determined from inputs of 16 years existing climatic data, crop data, soil and rain data.

3.8.1 Reference crop evapotranspiration (ETo)

FAO CROPWAT model for window 8.0 was used to determine reference crop evapotranspiration (ETo) using the available data. Although several methods exist to determine ETo, the Modified Penman-Monteith Method has been recommended as the appropriate combination method to determine ETo from climatic data, rainfall, temperature, humidity, sunshine and wind speed on a monthly basis. Crop factor (Kc) for every growth stage was taken from FAO (Allen et al., 1998) and then, ETo was calculated using equation 3.5.

3.8.2 Crop Water Requirement (CWR)

Direct measurements of procedures are laborious and time-consuming. Consequently, a large number of estimation methods have been developed. The four most widely known and used are the Blaney-criddle, Radiation, Penman and Pan Evaporation methods. Among them the Penman method recently further refined as modified FAO Penman Monteith method is best for mean estimates over short periods (Allen et al., 1998). In general, the crop water requirement (crop evapotranspiration, ETc) is calculated by multiplying the reference evapotranspiration, ETo, by corresponding crop coefficient, Kc.

$$\mathrm{ETc} = \mathrm{ETo} * \mathrm{Kc} \quad \ldots\ldots (3.4)$$

The reference crop evapotranspiration value, ETo, is defined as the rate of evapotranspiration from an extended surface of green grass cover of uniform height, actively growing, completely shading the ground and no shortage of water (Smith, 2000). The calculation of ETo requires only meteorological data.

Usually, the determination of Kc involves the knowledge of crop type and date of sowing, length of the total growing season, the duration of initial stage, the duration of crop development stage, the duration of the mid-season stage and the duration of late season stage and climatic data such as wind speed and humidity. The FAO Penman-Monteith method is recommended as the sole method for determining ETo.

$$\mathrm{ETo} = \frac{0.408\Delta(\mathrm{Rn}-\mathrm{G})+\frac{\gamma 900}{(\mathrm{T}+273)}U2(es-ea)}{\Delta+\gamma(1+0.34\mathrm{U2})} \quad \ldots\ldots(3.5)$$

Where ETo-reference evapotranspiration (mm/day), Rn-net radiation at the crop surface (MJ/m^2 day), T-air temperature at 2 m height (^{o}C), u_2 - wind speed at 2 m height (m/s), es-saturation vapour pressure (KPa), e_a-air vapour pressure (KPa), (e_s-e_a)-saturation vapor pressure deficit (KPa), Δ-slope vapour pressure curve (KPa/^{o}C) and γ-psychometric constant (KPa/^{o}C)

After setting out of crop evapotranspiration, it is possible to determine net irrigation water requirement by subtracting effective rainfall from ETc during the investigational season and it can be expressed by using equation 3.6.

$$\mathrm{NIR} = \mathrm{ETc} - \mathrm{Pe} \quad \ldots\ldots (3.6)$$

Where; NIR is net irrigation water requirement of the crop in mm, and Pe is effective rainfall during the growth period of the crop in mm. Then the gross irrigation requirement using equation 3.7.

$$\mathrm{GIR} = \frac{\mathrm{NIR}}{\mathrm{Ea}} \quad \ldots\ldots (3.7)$$

Where; GIR is gross irrigation water requirement of the crop in mm, NIR is net irrigation water requirement of the crop in mm and Ea is application efficiency in percentage.

3.8.3 Effective Rainfall (Peff)

The proportion of rainfall that can enter and support plant evapotranspiration is said to be effective rainfall (Peff). There are four methods to calculate effective rainfall viz. fixed percentage of rainfall, dependable rainfall, Empirical formula, USDA soil conservation service (Dastane, 1974). Of the various methods used for CWR calculation, dependable rainfall (80% probability of exceedance) method has been used to estimate the effective rainfall for this study area. This formula used for design purposes where 80% probability of exceedance is required.

$$\mathrm{Peff} = 0.6 * \mathrm{P} - 10 \text{ for Pmonth} \leq 70 \text{ mm} \quad \ldots\ldots (3.8)$$

$$\mathrm{Peff} = 0.8 * \mathrm{P} - 24 \text{ for Pmonth} > 70 \text{ mm}$$

Where, Pmonth = Monthly rainfall, mm and Peff = effective rainfall

3.8.4 Soil Type

The dominant soil type in the Fogera plains is black clay soil (ferric vertisols) show in Figure 3-6 (Fogera Woreda Pilot Learning Site Diagnosis and Program Design, January 2005). The dominant soil type in the Fogera plains is black clay soil (Eutric vertisols), while the mid and high altitude areas are Haplic Luvisols and Eutric Fluvisols are respectively (Getachew Ewonetu, January 2013). From the literature review and observation texturally, black clay soil was used for this study.

The soil data required by the CROPWAT model includes, total available soil moisture, maximum rain infiltration rate, maximum root depth, initial soil moisture depletion and initial available soil moisture. The soil data used in the model was the same for all crops except the maximum root depth. The above data of soil collected from CROPWAT data base and FAO tables.

3.8.5 Irrigation efficiency (Ep)

To complete the evaluation of the demand, the efficiency of the water distribution system and of application must be known. The gross requirement of water for irrigation system is very much dependent on the overall efficiency of the irrigation system, which in turn is dependent on several factors: method of irrigation, type of canal (lined and/or unlined), method of operations (simultaneously and continuous or rotational water supply), and availability of structures (for controlling and distribution and measuring and monitoring).

In the study area the irrigation is surface irrigation method (using furrows or flooding) directly from the river to the field by motor pump. The overall/scheme efficiency for the practiced surface irrigation method is considered to be the field application efficiency (since the water pumped from the source is directly applied to the field and hence the conveyance efficiency is not so relevant) that, (Smith, 2000), (Teklu, 2016) and (Norman, 1999), suggested 60% attainable water application efficiencies for surface irrigation system from literature review and field observation of poor management of water by farmers in the field was used.

3.8.6 Irrigation Scheduling (IS)

Irrigation scheduling is the process of determining the time to irrigate and how much water is to be applied in each irrigation. For efficient utilization of water, irrigation scheduling is required. Irrigation schedules are considered to either fully or partially provide the estimated water requirements of the crop. For the selected crops the irrigation scheduling has been carried out which shows the amount of water to be supplied at a specific period of time to these crops. To find out irrigation scheduling irrigating at critical depletion approaches is used.

Irrigation scheduling is one of the managerial activities that aim at effective and efficient utilization of water. It is also expressed in terms of frequency rate and duration of how water is delivered to a farm unit. The number and timing of irrigation vary widely for different crops. It is the function of crops, soil and climate. In this study it has tried to determine the irrigation intervals of the selected crops.

4. RESULTS AND DISCUSSIONS

4.1 Accuracy assessment

The accuracy assessment is used to determine the correctness of the classified image. It was performed using confusion matrix, a total of 317 ground control points (GCP) and the Google Earth Image as a reference were used to validate the classified image of 2001, 2010 and 2017. The results of total accuracy image classifications are presented in the Tables 4-1, 4-2 and 4-3.

Table 4-1 Total accuracy of 2001 classification

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Irrigated Agri land	79	131	68	86.08%	51.91%
Non-Irrigated Agri land	70	60	56	80.00%	93.33%
Forest/shrubs	66	49	32	48.48%	65.31%
Flooded Agri land	102	77	59	57.84%	76.62%
Totals	317	317	215		

Overall Classification Accuracy = 67.82%

Overall Kappa Statistics = 0.6612

Table 4-2 Total accuracy of 2010 classification

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Irrigated Agri land	79	76	60	75.95%	78.95%
Non-Irrigated Agri land	70	91	65	92.86%	71.43%
Forest/shrubs	66	91	61	92.42%	67.03%
Flooded Agri land	102	59	55	53.92%	93.22%
Totals	317	317	241		

Overall Classification Accuracy = 76.03%

Overall Kappa Statistics = 0.6626

Table 4-3 Total accuracy of 2017 classification

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Irrigated Agri land	79	74	65	82.27%	87.83%
Non-Irrigated Agri land	70	80	65	92.86%	81.25%
Forest/shrubs	66	87	55	83.33%	63.22%
Flooded Agri land	102	76	70	68.63%	92.11%
Totals	317	317	255		

Overall Classification Accuracy = 80.44%

Overall Kappa Statistics = 0.7608

The overall accuracy that is the user's accuracy, producer's accuracy, and Kappa statistics were calculated from the error matrix, shown in the (Tables 4-1, 4-2, 4-3), the overall accuracy of the classification for 2001 was 67.82% with Kappa coefficient of 0.6612, the overall accuracy of the classification for 2010 was 76.03% with Kappa coefficient of 0.6626 and the overall accuracy of the classification for 2017 was 80.44% with Kappa coefficient of 0.7608.This indicates that the kappa value of 0.6612, 0.6626 and 0.7608 represents a probable 67.82, 76.03 and 80.44 percent better accuracy than if the classification resulted a random unsupervised classification. According to Monserud and Leemans (1992), classification scale, in this study the classification lies on good and very good agreement.

4.2 Land Cover Changes in the study period

Temporal analysis was carried out to describe land cover change pattern and overall land use changes with time. This was done after image classification of the three land cover maps for the periods 2001, 2010 and 2017 and results for each time period can be expressed as follows:

❖ Magnitude of Land Cover in 2001

The land cover map of 2001 (Figure 4-1 and Table 4-4) indicates that 10.61% of the study area was covered by irrigated agricultural land, 71.46% by non-irrigated agricultural land, and 6.45% by forest/shrubs and 11.48% flooded agricultural land. In this period, the non-irrigated agriculture land cover was found in most part of the study area; irrigated agricultural land was more dominated by others as shown in (Figure 4-1 and Table 4-4). More of non-irrigated agricultural land was identified on the upper reach of the river course under study and irrigation activities were relatively intense in the middle of the reach under consideration.

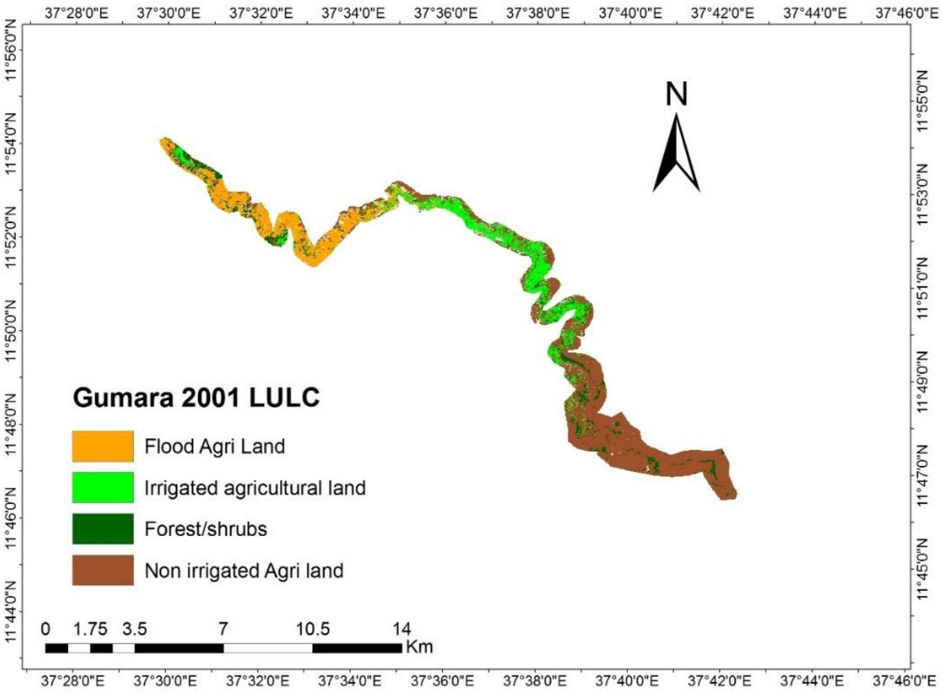


Figure 4-1 Gumara River periphery 2001 land use/cover

❖ Magnitude of Land Cover and Land Cover Changes in 2010

The land cover map of 2010 (Figure 4-2 and Table 4-4) indicates that 42.98% of the study area was covered by irrigated agricultural land, 42.16% by non-irrigated agricultural land, and 12.57% by forest/shrubs and 2.30% flooded agricultural land. When the land cover area of 2010 is compared with the 2001, it is observed that irrigated agricultural land increased by 32.37%, non-irrigated agricultural land decreased by 29.30%, forest/shrubs increased by 6.12% and flooded agricultural land decreased by 9.18%.

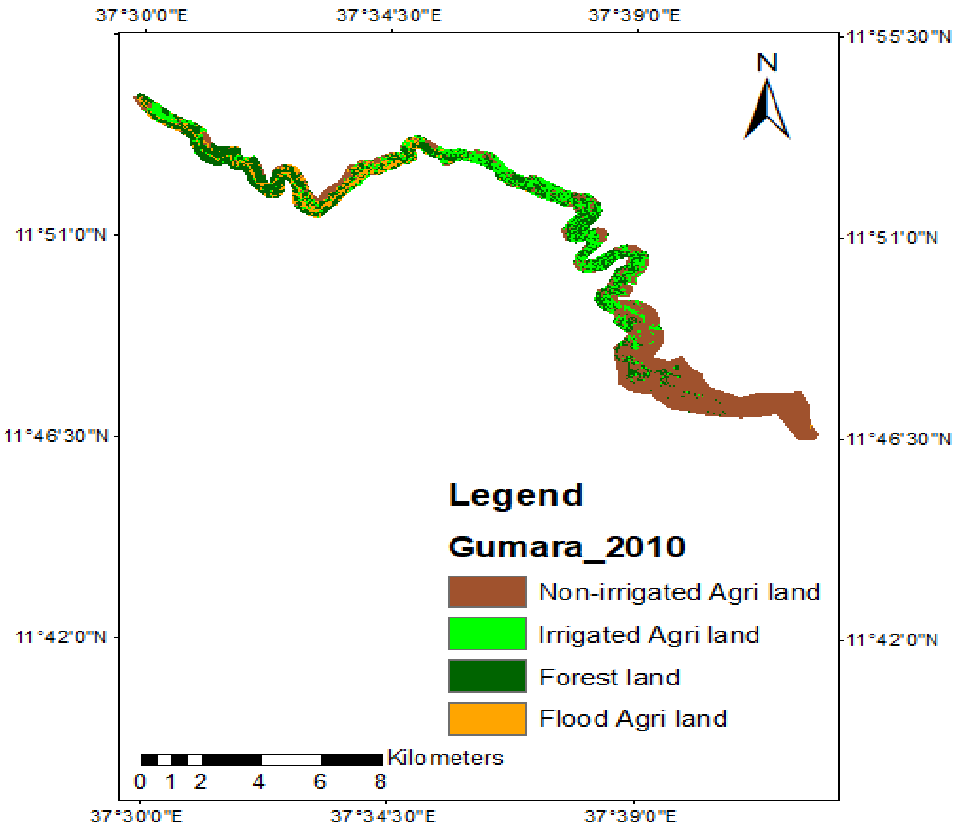


Figure 4-2 Gumara River periphery 2010 land use/cover

Table 4-4 Gumara land cover change from 2001-2010

Class Name	Value	Area (ha)		Area in %		Change	
		2001	2010	2001	2010	in (ha)	in %
Irrigated Agri land	1	322.82	1307.45	10.61	42.98	984.63	32.37
Non-Irrigated Agri land	2	2173.85	1282.46	71.46	42.16	-891.40	-29.30
Forest/shrubs	3	196.12	382.27	6.45	12.57	186.16	6.12
Flood Agri land	4	349.28	69.89	11.48	2.30	-279.39	-9.18
Total area		3042.07	3042.07	100	100		0.00

From periods 2001 to 2010 the land cover change shows there was highly expansion of irrigated agriculture and increment of forest/shrubs whereas the non-irrigated agricultural land and flooded agricultural land were significantly decreased in this period. The reason for increasing of forest/shrubs and irrigated agriculture land in this study period was due to the decrement of flooded land body and non-irrigated agricultural land, flood land and non-irrigated agricultural land was converted to forest/shrubs and irrigated agriculture land.

❖ **Magnitude of Land Cover and Land Cover Changes in 2017**

The land cover map of 2017 is also presented in Figure 4-3 and Table 4-5 indicates that 75.86% of the study area was covered by irrigated agricultural land, 17.98% by non-irrigated agricultural land, and 3.33% by forest/shrubs and 2.84% flooded agricultural land.

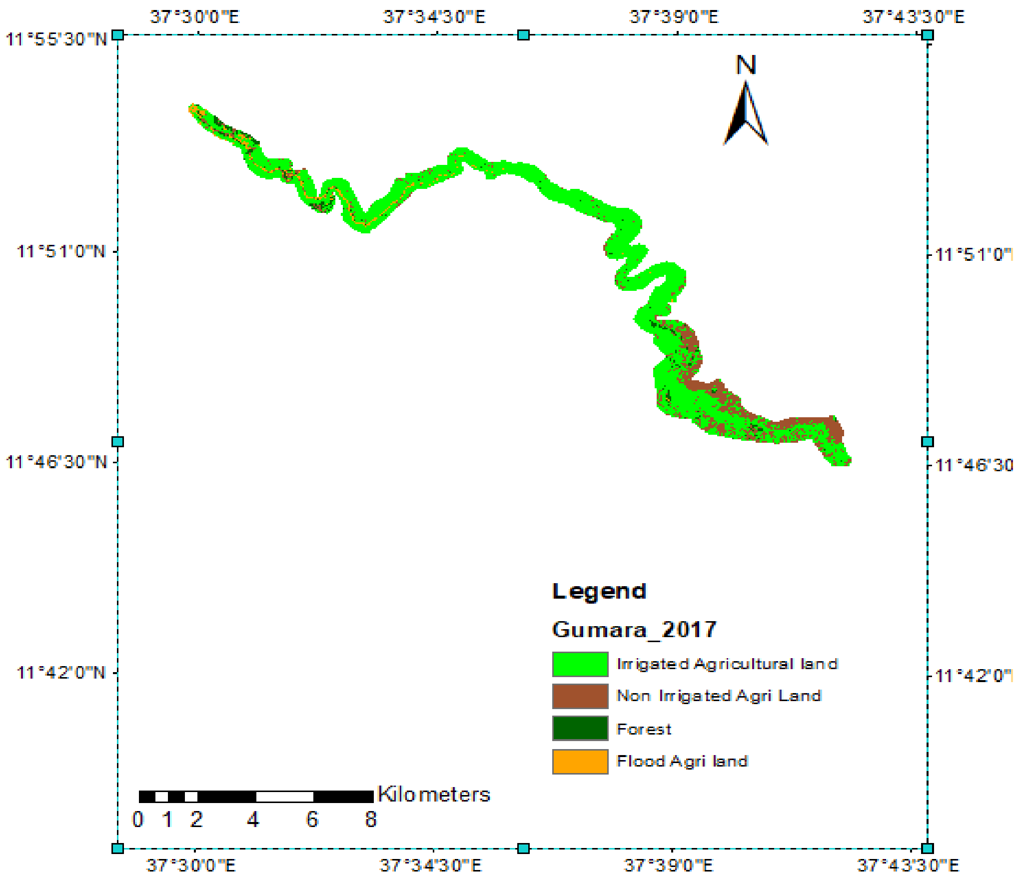


Figure 4-3 Gumara River periphery 2017 land use/cover

Table 4-5 Gumara land cover change from 2010-2017

Class Name	Value	Area in (ha)		Area in %		Change	
		2010	2017	2010	2017	in (ha)	in %
Irrigated Agri land	1	1307.45	2307.71	42.98	75.86	1000.26	32.88
Non-Irrigated Agri land	2	1282.46	546.82	42.16	17.98	-735.64	-24.18
Forest/shrubs	3	382.27	101.28	12.57	3.33	-281	-9.24
Flooded Agri land	4	69.89	86.26	2.30	2.84	16.37	0.54
Total area		3042.07	3042.07	100.00	100.00		0.00

The land cover change comparison between the years 2010 and 2017 shows that the irrigated agricultural land increased by 32.88%, non-irrigated agricultural land decreased by 24.18%, forest/shrubs decreased by 9.24% and flooded/ponds increased by 0.54%. Flooded/ponds increased in this time period, due to the flood that occurred in 2016 rainy season as confirmed by the local people in Dera woreda, Jegina kebele.

- **Overall Land Cover Changes from 2001 to 2017**

The land cover change comparison in Table 4-6 indicates that between these years irrigated agricultural land increased by 65.25%, whereas non- irrigated agricultural land, forest/shrubs and flooded Agri land decreased by 53.48%, 3.12% and 8.65 %.

Table 4-6 Gumara land cover change from 2001-2017

Class Name	Value	Area (ha)		Area in %		Change	
		2001	2017	2001	2017	in (ha)	in %
Irrigated Agri land	1	322.82	2307.71	10.61	75.86	1984.89	65.25
Non-Irrigated Agri land	2	2173.85	546.82	71.46	17.98	-1627.04	-53.48
Forest/shrubs	3	196.12	101.28	6.45	3.33	-94.84	-3.12
Flood Agri land	4	349.28	86.26	11.48	2.84	-263.02	-8.65
Total area		3042.07	3042.07	100	100		0.00

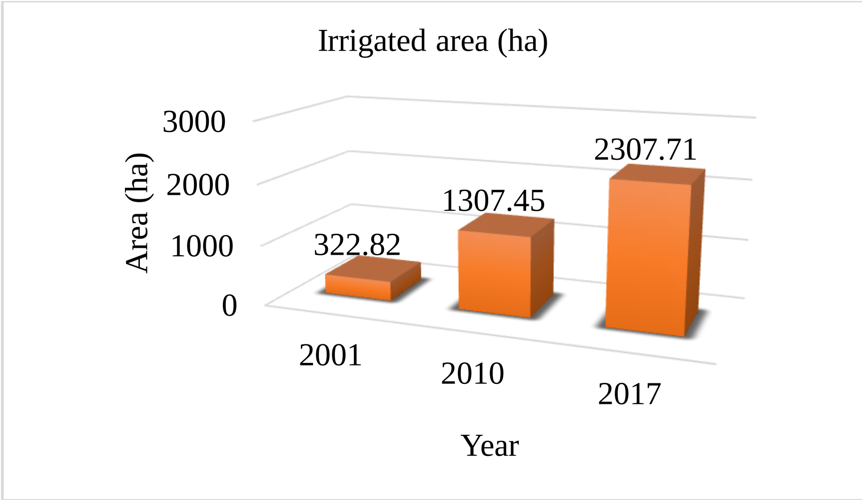


Figure 4-4 Irrigated area expansion trend

This study shows that non-irrigated agricultural land, forest/shrubs and flooded agricultural land revealed negative rate of change between 2001 and 2017 while areas of irrigated agricultural land increased (Table 4-7). This indicate that non-irrigated agricultural land, forest/shrub and Flooded agricultural land have been converted possibly into cultivation. Similar to this study, a study conducted by ((Flugel, 1995; Kahsay, 2004), (Hadgu, 2013), (Kindu et al., 2013), (Zeleke and Hurni, 2001), Yeshaneh et al (2013), Bewket and Abebe (2005) and (Geremew, 2013)), indicated that there has been agricultural land size expansion at the expense of natural vegetation cover lands and marginal areas without any appropriate conservation measures.

- **Comparing land cover result with interview of irrigated agricultural land**

The land cover result show that irrigated agricultural land coverage in 2017 was 2307.71ha from the total area of 3042.07ha while from the survey at the end of 2017 from the unknown total hectares, 3988.125ha is irrigated. This show the irrigated agricultural land coverage area is not well known among the irrigator and experts around the area, but both the result from the model and interview show there is high expansion so knowledge and quantification of land use/cover change in this area is important for many purposes to be practiced and knowing the current extent.

At the starting time approximately, there were 5-10 motor pumps serviced by the Government to some farmers but now a time from the field survey in the study area there are different types of motor pumps and reaches to 1530 in number and 4848 users at the end of 2017.

4.3 Crop Water Requirement (CWR)

The main irrigation season for the study area is from November to June, consisting of two irrigation seasons. The first season of irrigation is from November up to February to March and the second season is from March up to June. The results of the potential evapotranspiration (ETo) (Appendix table 2.2), Eff rain (Table 4-7 and Appendix table 2.3), average ETc and the irrigation requirements are shown on (Table 4-7 and Appendix table 2.5).

Table 4-7 Average ETc, Eff rain and per season irrigation requirement

	Average ETc	Eff rain	Irr. Req.
Crops	mm/season	mm/season	mm/season
Onion	338.2	0.1	338.1
Tomato	322.1	0	322.1
Potato	331.3	0	331.3
Maize	383.7	168.8	249.5

4.3.1 Total irrigation needed on monthly basis

To determine the total irrigation requirement, the percentage area coverage for selected crops from the survey at the end of 2017 (Appendix table 2.6) and the land use/cover irrigated area (Table 4-6) multiply the Per month irrigation requirements for selected crops (Table 4-8) by the basis of this, it can calculate demand for each crop grown for each studying years that are 2001, 2010 and 2017. The brief calculation is shown on Appendix table 2.7.

Table 4-8 Per month irrigation requirements

	Crop demand (mm/month)			
Month	Onion	Tomato	Potato	Maize
Nov	69.4	30.9	25.7	
Dec	79	69.9	71.1	
Jan	97.6	107.4	108.7	
Feb	92.1	101.7	99.2	
Mar		12.2	26.6	42.4
Apr				104.5
May				89
Jun				13.6

Table 4-9 Total demand on monthly base for the year 2017, 2010 and 2001

	Total demand in 2017				
Month	Onion (m^3/month)	Tomato (m^3/month)	Potato (m^3/month)	Maize (m^3/month)	Total (m^3/month)
Nov	1329287.11	92700.71	17792.44		1439780
Dec	1513165.45	209701.61	49223.45		1772091
Jan	1869429.72	322202.47	75254.42		2266887
Feb	1764082.76	305102.34	68677.45		2137863
Mar		36600.28	18415.53	802344.61	857360
Apr				1977476.70	1977477
May				1684166.76	1684167
Jun				257355.82	257356
Total	6475965.03	966307.41	229363.30	4721343.89	12392980

	Total demand in 2010				
Month	Onion (m^3/month)	Tomato (m^3/month)	Potato (m^3/month)	Maize (m^3/month)	Total (m^3/month)
Nov	753117.35	52520.27	10080.44		815718
Dec	857294.97	118807.98	27887.91		1003991
Jan	1059139.10	182546.17	42635.94		1284321
Feb	999454.00	172857.96	38909.71		1211222
Mar		20736.16	10433.45	454574.22	485744
Apr				1120353.91	1120354
May				954177.01	954177
Jun				145806.82	145807

	Total demand in 2001				
Month	Onion (m^3/month)	Tomato (m^3/month)	Potato (m^3/month)	Maize (m^3/month)	Total (m^3/month)
Nov	185950.78	12967.68	2488.94		201407
Dec	211673.07	29334.65	6885.75		247894
Jan	261510.03	45072.13	10527.16		317109
Feb	246773.29	42680.03	9607.12		299060
Mar		5119.93	2576.10	112238.06	119934
Apr				276624.46	276624
May				235594.04	235594
Jun				36000.89	36001

4.3.2 Supply-Demand relation

From the interview averagely, farmers irrigate 10hr/day. To determine the actual amount of water used by the smallholder irrigators are multiplied each monthly supply by 10hr/day, show in Appendix Table 2-10.

Table 4-10 Supply (m3/irrigation) and demand (m3/month)

		2017	2010	2001
Month	Supply (m^3/irrn.)	Demand (m^3/month)	Demand (m^3/month)	Demand (m^3/month)
Nov	13000619	1439780	815718	201407
Dec	7559534	1772091	1003991	247893
Jan	3921404	2266887	1284321	317109
Feb	2301305	2137863	1211222	299060
Mar	2232190	857360	485744	119934
Apr	1915010	1977477	1120354	276624
May	3567235	1684167	954177	235594
Jun	16791940	257356	145807	36001
Total	51289236	12392980	7021333	1733624

To know whether there is scarcity or surplus supply from the source, demand-supply analysis was conducted for the irrigation period and the results are shown on Table 4-11 for each studying years.

Table 4-11 Over all Supply- Demand for the years 2001, 2010 and 2017

	2017	2010	2001
Month	Supply-demand (m^3/month)	Supply-demand (m^3/month)	Supply-demand (m^3/month)
Nov	11560839	12184901	12799212
Dec	5787443	6555543	7311640
Jan	1654517	2637083	3604294
Feb	163443	1090083	2002245
Mar	1374829	1746446	2112256
Apr	-62467	794656	1638385
May	1883069	2613058	3331641
Jun	16534584	16646133	16755939

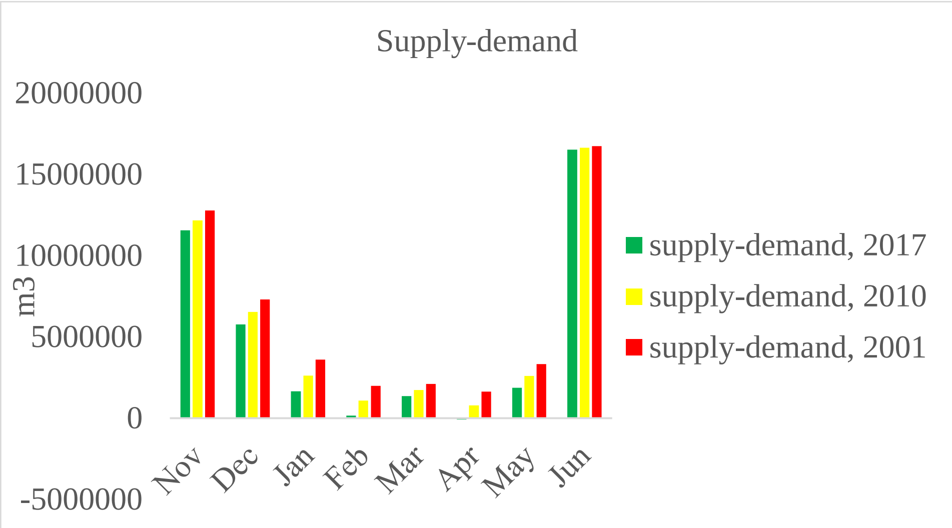


Figure 4-5 Supply-Demand of 2001, 2010, 2017

CROPWAT model was used to calculate the irrigation water requirement for major crops. Based on the result of CROPWAT model and survey analysis, the total irrigation requirement in 2017 was 1439780, 1772091, 2266887, 2137863, 857360, 1977477, 1684167, 257356 (m^3/month) for Nov, Dec, Jan, Feb, Mar, Apr, May and Jun respectively. The analysis also indicated the total water demand of all small holder users of Gumara River during the irrigation season from Nov to Jun. The available river flow from Nov to Jun was 13000619, 7559534, 3921404, 2301305, 2232190, 1915010, 3567235, 16791940 and 51289236 (m^3/irrn.) respectively. From the eight months, the demand and the supply showed a gap during April from the source but from the survey there is shortage throughout the irrigation period. The total shortage of supply during this month was 62467 (m^3/month). During this month, there was also conflict between users. Therefore, in order to solve water shortage, alternative source of water supply like ground water and water harvesting technologies should be studied and integrated water management system should be implemented to improve the efficiency of irrigation water in the area.

4.4 Irrigation scheduling

Table 4-12 Irrigation scheduling for Onion, Tomato, Potato and Maize

Onion

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
01-Nov	1	Init	0	0.71	71	53	32.1	0	0	53.5	6.19
12-Nov	12	Init	0	1	100	33	22.8	0	0	37.9	0.4
22-Nov	22	Init	0	1	100	33	25.4	0	0	42.4	0.49
03-Dec	33	Dev	0.8	1	100	32	27.4	0	0	45.7	0.48
14-Dec	44	Dev	0	1	100	31	29.7	0	0	49.4	0.52
25-Dec	55	Dev	0	1	100	31	32.2	0	0	53.7	0.57
05-Jan	66	Dev	0	1	100	30	34.3	0	0	57.1	0.6
17-Jan	78	Mid	0.7	1	100	31	37.8	0	0	62.9	0.61
29-Jan	90	Mid	0	1	100	32	38.2	0	0	63.7	0.61
09-Feb	101	Mid	0	1	100	31	37.4	0	0	62.3	0.66
20-Feb	112	End	0	1	100	31	37.6	0	0	62.6	0.66
28-Feb	End	End	0	1	0	16					

Tomato

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
15-Nov	1	Init	0	0.71	71	53	27.8	0	0	46.3	5.36
22-Nov	8	Init	0	1	100	31	22.3	0	0	37.2	0.62
02-Dec	18	Init	0	1	100	32	31.9	0	0	53.2	0.62
16-Dec	32	Dev	0	1	100	33	45.8	0	0	76.3	0.63
03-Jan	50	Dev	0.6	1	100	38	71.5	0	0	119.2	0.77
26-Jan	73	Mid	0	1	100	41	82.4	0	0	137.3	0.69
19-Feb	97	End	0	1	100	45	89.1	0	0	148.6	0.72
04-Mar	End	End	0	1	100	19					

Potato

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
15-Nov	1	Init	0	0.67	67	52	31.7	0	0	52.8	6.12
24-Nov	10	Init	0	1	100	25	18.2	0	0	30.3	0.39
05-Dec	21	Dev	0	1	100	27	23.1	0	0	38.5	0.41
16-Dec	32	Dev	0	1	100	28	27.6	0	0	46.1	0.48
26-Dec	42	Dev	0	1	100	29	32.2	0	0	53.6	0.62
06-Jan	53	Mid	0	1	100	32	38.5	0	0	64.2	0.68
17-Jan	64	Mid	0.7	1	100	30	36.6	0	0	60.9	0.64
28-Jan	75	Mid	0	1	100	32	38.3	0	0	63.9	0.67
07-Feb	85	Mid	0.2	1	100	31	36.8	0	0	61.3	0.71
20-Feb	98	End	0	1	100	39	46.8	0	0	78	0.69
09-Mar	End	End	0.4	1	100	40					

Maize

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
10-Mar	10	Init	0	0.88	96	61	52.5	0	0	87.4	1.01
20-Mar	20	Init	0	1	100	21	22.8	0	0	38	0.44
04-Apr	35	Dev	0	1	100	28	41.9	0	0	69.8	0.54
19-Apr	50	Dev	0	1	100	32	59	0	0	98.4	0.76
04-May	65	Mid	0	1	100	22	45	0	0	75	0.58
19-May	80	Mid	0	1	100	14	28.5	0	0	47.4	0.37
03-Jun	95	Mid	22.1	1	100	7	13	0	0	21.7	0.17
23-Jun	115	End	39.6	1	100	1	1.6	0	0	2.7	0.02
28-Jun	End	End	0	1	0	1					

Comparison of model to surveyed traditional irrigation practice of water use

The results are shown on Table 4-13 with respect to irrigation intervals for irrigation.

Table 4-13 Average model and traditional irrigation practice scheduling interval

Crops	Average model irrigation interval	Average traditional irrigation practice interval	Gap b/n model and traditional
Onion	every 11 days	every 4 days	3
Tomato	every 16 days	every 7 days	2
Potato	every 11 days	every 7 days	2
Maize	every 15 days	every 21 days	1

In relation to the actual time interval (average) that the farmers used to irrigate from the field survey and comparison of their irrigation schedule with the model results, from the CROPWAT model, Onion, Tomato, Potato and Maize should be irrigated every 11, 16, 11 and 15 days but farmers irrigate every 4, 7, 7 and 21 days. This indicates more water application by the traditional irrigation which indicates poor management of the irrigation and hence loss of water due to exccessive application of water to the crop without any scientific scheduling. Table 4-14 shows the results of the total water used in the irrigation period by the two methods.

Table 4-14 Demand used by the irrigator traditionally and from model in 2017

	Onion ($M\ m^3$)	Tomato ($M\ m^3$)	Potato ($M\ m^3$)	Maize ($M\ m^3$)	Total ($M\ m^3$)
Cropwat Model	6.48	0.97	0.23	4.72	12.39
Traditional irrigation	19.43	1.93	0.46	4.72	26.54
Difference	12.95	0.97	0.23	0.00	14.15

The CROPWAT result shows that the total water requirement for Onion, Tomato, Potato, Maize are 6.48, 0.97, 0.23, 4.72 $M\ m^3$ respectively resulting in a total of 12.39 $M\ m^3$ water consumption but the currently the traditional irrigators use 19.43, 1.93, 0.46, 4.72 $M\ m^3$ of water for the above-mentioned crops respectively resulting in a total of 26.54 $M\ m^3$ in the season. From this there is a total of around 14.15 $M\ m^3$ loss. This shows the shortage for the irrigation is both from the source and due to poor management practice at the field among the irrigators. At the same time, water stress was observed during irrigation, as the applied water did not match the water needs of different crops. Moreover, traditional farmers engaged in crop production are aware of some kind of scheduling of water to the crops, but their knowledge is based mostly on intuition and traditional perception rather than on any scientific basis.

4.5 Relevant Interview Response and Field survey

To assess farmers' perception about small holder motor pump irrigation 98 households' respondents were selected randomly from 4848 households for the six sampled kebeles and interviewed with semi-structured questionnaire. The questionnaire stressed on the personal information of respondent, general overview about the practice, management practices, sources of disagreement and resolution mechanisms, about motor pump and factors influencing the adoption, support services, extension and training.

A) Characteristics of the irrigation beneficiaries

According to the interview 88.78% and 11.22% of the beneficiaries were male and female households respectively. About 57.14% of the beneficiary household were illiterate, 22.45% can read and write only, 13.27% were elementary. On the other hand, about 7.14% of beneficiary household heads attended high school. These shows the majority small holder farmers are males and the majority are illiterate shown on Table 4-15.

Table 4-15 Characteristics of beneficiary households

Characteristics		N=98	
		Frequency	Percent
Sex	Male	87	88.78
	Female	11	11.22
Educational level	Illiterate	56	57.14
	Read and write only	22	22.45
	Elementary	13	13.27
	High school	7	7.14

Where, N= number of respondents,

B) Management practices

Table 4-16 Decision on the schedule of irrigation

Who decides on how much and when to irrigate	No of Respondents	Percent
DAs	12	12.2
Beneficiary Households	86	87.8
Total	98	100

The water distribution in the small holder is managed by the beneficiaries themselves without designed irrigation schedule. There is no any written schedule, small holder farmers irrigate randmly by their traditional system. Only 12.2% of the respondent farmers confirmed that water supply to each farmer is decided by DAs, this is done when there is water shortage and 87.8% farmers confirmed that the distribution was managed by beneficiary Households based on their irrigation schedule that day until he/she completes irrigating the fields.

Table 4-17 Response of households on the system of irrigation

System of irrigation	No of Respondents	Percent
Furrow	91	92.9
Flooding	7	7.1
Total	98	100

According to the respondents, 92.9% of the respondents replied that they follow furrow irrigation system and only 7.1% flooding irrigation system.

Table 4-18 Response of households on the criteria to decide when to irrigate

What criteria do you use to decide when to irrigate?	No of Respondents	Percent
Wait until the crops leaves wilt	33	33.7
Check the soil near the roots	58	59.2
When it is dry	7	7.1
Irrigate every day	-	-
Total	98	100

33.7% of the respondents replied that they will wait until the crops leaves wilt, 59.2% of the respondents replied that they irrigate their crop when the soil near the crop roots is dry and 7.1% of the respondents replied that they irrigate their crop when it is dry Table 4-18.

Figure 4-6 Condition that farmers realize as the indication of irrigation required

C) Factors influencing the adoption of the motorized water pump for irrigation

Response of households on the factors influencing the adoption of the motorized water pump for irrigation are; water shortage from the source, information awareness, motor pumps are expensive, motor pump quality, economy, markets and services access to fuel, finance, transport, environmental factors. lack of spare parts and maintenance service, Lack of technical know-how, motor technical is not available in the nearest, new motor pumps take very much benizn, spare parts quality and high cost of fuel.

a) b)

Figure 4-7 Transporting pump equipment b) Farmer and pump technician

Table 4-19 Households response on the change of water from the source

What type of change is happening on irrigation water from the source year to year?	No of Respondents	Percent
Increase	-	-
Decrease	98	100
No change	-	-
Total	98	100

100% of respondents sayies there is decrement of water for the motorized pump irrigation directly from the Gumara river year to year by different causes.

Table 4-20 Households response on the cause of water shortage from the source

What is the cause of the shortage?	No of Respondents	Percent
Due to sediment deposition	33	33.7
Due to the use of other organization	-	-
Due to the expansion of motor pump irrigation	53	54.1
Due to the building of traditional dam of the tributary springs and rivers above	12	12.2
Total	98	100

According to the respondents, 33.7% of the respondents replied that the shortage of water is due to sediment depostion, 54.1% of the respondents due to the expansion of motor pump irrigation, 12.2% of the respondents due to the building of traditional dam of the turbiutary springs and rivers above and lateral.

Figure 4-8 Sediment problem

Figure **4-9 Pumping river water for irrigation**

The irrigation system is taking water directly from the Gumara River by motor pumps to the farmer's uses field, this expansion of motor pumps and users case shortage of irrigation water.

From the empirical literature studies about factors that influencing the adoption of the motorized water pump for irrigation, that supported in this research are studies by ((Tadesse et al., 2008), (Ellis and Mdoe, 2003), (Caswell et al., 2001)) that are access to fuel, Human capital, Information, extension contact. But not supported studies by (Caswell et al., 2001; Khanna, 2001) and (Knowler and Bradshaw, 2007), that are household head's age, Gender, Labour availability, are not factors affecting as shown from the investigation.

D) Source of disagreement in the irrigation and resolution mechanisms

According to the respondents, 89.8% of household respondents believe that there is disagreement between the beneficiaries of Gumara river for motorized pump irrigation.

Respondents said that there is disagreement between the two woredas that is between Fogera and Dera, between the upper/middle/lower stream user, between the boarder farm plot by water passage through their farm boarder. 61.22% of household respondents believe that the disagreement is due to water passage through plot borders and 38.78% due to water shortage; spatially Shina kebele and Kuhar Mikael kebele there is extremely disagreement due to water shortage.

Figure 4-10 The main disagreement area

Table 4-21 Disagreement resolution methods

Resolution methods	No of Respondents	Percent
By law	3	3.1
By Kebele Administration	27	27.5
By elders	68	69.4
Total	98	100

According to the respondents, 69.4% of the respondents replied that the disagreement that originated is resolved by elders, 27.5% by kebele Administration and 3.1% by law. These show that the disagreement between the farmers not reach to the law it resolved by themselves.

E) Support services

About 94.9% beneficiary respondents have not got institutional support. There was only Agro-Big institutional support in that lower Gumara motor pump irrigation schemes. According to the respondents there is no strong body that can materialize the motorized pump irrigation scheme.

F) Extension and Training

Given the potential benefit that the scheme could provide to the beneficiary farmers and the local community, a qualified extension agent would have been imperative. Farmers were not getting advice from an irrigation agronomist or from a qualified development agent. There were no organizations committed towards providing farmers with the needful training and extension services. About 76.5% beneficiary respondents have not got adequate capacity building training on how could use motor pump effectively and efficiently, effective use of the available water resource, and management of irrigation scheme.

Agricultural development office has already established in the study area kebeles to provide agricultural extension services and trainings to the local farmers. But the DAs have not close and day to day contacts with farmers and are not responsible to implement the different agricultural programs.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study has been conducted by integrating satellite data, ERDAS and GIS tools, CROPWAT model and semi-structured questionnaire to assess the land use/cover change (irrigated expansion) of the study area, to identify management practices and to investigate factors influencing the adoption of the motorized water pump for irrigation. Satellite data for the study periods of 2001, 2010, 2017 were applied to generate land cover maps through a maximum likelihood supervised image classification algorithm. The accuracy assessment processes have also been done. The overall accuracy of land use/cover maps generated in this study had got an acceptable value of above the minimum threshold.

Pertaining to the objectives of the study, the following major conclusions are made:

- Land cover classification result show that from a period of 2001 to 2017 irrigated agricultural land increased by 65.25% (from 322.82ha in 2001 to 2307.71ha in 2017), non- irrigated agricultural land decreased by 53.48%, forest/shrubs decreased by 3.12% and flooded agricultural land decreased by 8.65 %. Generally, there was high expansion of irrigation along the lower course of Gumara River.
- The CROPWAT result show that the crop water requirement (CWR in mm) for Onion, Tomato, Potato and Maize are 338.1, 322.1, 331.3 and 249.5 respectively.
- The annual irrigation water consumption from the river increased from 1733624 m^3 in year 2001 to 12392980 m^3 in year 2017 for irrigation, whereas the average annual supply of water for the irrigation period (Nov-June) from the river is 51289236 m^3 (nearly constant supply).
- Supply-Demand relation shown there is water shortage in 2017 on April from the source and the shortage may increase in the future as irrigated area will expand whereas the supply remains more or less constant.
- Irrigation scheduling show that in relation to the actual time interval (average) that the farmers used to irrigate from the field survey and compare their irrigation schedule with the model results Onion, Tomato, Potato and Maize should be irrigated every 11, 16, 11 and 15 days but farmers irrigate every 4, 7, 7 and 21 days respectively, this indicate miss application of water to the crop without any scientific scheduling.

- ❖ The CROPWAT result shows that the total irrigation requirement for Onion, Tomato, Potato, Maize are 6.48, 0.97, 0.23, 4.72 M m3 respectively resulting in a total of 12.39 M m^3 water consumption but the currently the traditional irrigators use 19.43, 1.93, 0.46, 4.72 M m^3 of water for the crops mentioned respectively resulting in a total of 26.54 M m^3 in the season. From this there is a total of around 14.15 M m^3 loss, in the year 2017.
- ❖ From the investigation and interview the factors influencing the adoption of the motorized water pump for irrigation are water shortage from the source, information awareness, cost of water lifting technologies, motor pump quality, economy, markets and services access to fuel, finance, transportation, environmental factors, lack of spare parts and maintenance service, motor pump technical is not available in the nearest, new motor pumps take very much benizn, spare parts quality and high cost of fuel.

Generally, based on the findings of the study, the result showed that in the study years of the small holder motorized pump irrigation implementation, there was high expansion of irrigation even though there were factors influencing the adoption of motor pump and poor irrigation management practices.

5.2 Recommendation

The results of this specific study have shown that studying small holder farmer-based irrigation practice by using remote sensing, GIS, ERDAS tools and CROPWAT model are important. Therefore, from the conclusion reached, the following recommendations are drawn:

- ❖ As the expansion of irrigation continues, it is recommended to work on improving the efficiency of water utilization, to look for alternative water sources (groundwater and water harvesting) and to raise the awareness of the irrigators on the value of water.
- ❖ Even though there are factors affecting the adoption there is expansion of irrigation but decreasing of water from the source and poor management practices so, WUA should be organized for the efficient and effective water use, furrow irrigation should better than flooding.
- ❖ Moreover, traditional farmers engaged in crop production are aware of some kind of scheduling of water to the crops, but their knowledge is based mostly on intuition and traditional perception rather than on any scientific basis. Scientific irrigation scheduling and scientific choice of cropping pattern should be better on the basis of water availability, soil type, and regional agro-climate conditions.
- ❖ Training on irrigation agronomy and management should be provided by DAs and beneficiary farmers to equip them with sufficient techniques.
- ❖ Since factors affecting adoption are cost of motor pumps, Credits supplying, marketing, transport, availability of motor pump technician so policy makers should consider marketing exchange, Credits supplying institutions should available, motor pump technician should available nearly, it should better motor pumps fabricate inside the country rather than importing and DAs should better work friendly with farmers.

Finally, in this research only the expansion, management practices and factors influencing the adoption of the motorized water pump for irrigation were assessed, further studies on investigating Ground water source and water harvesting, river sedimentation, water budget, small holder cooperation working should be needed.

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APPENDIX

Appendix 1 Questionnaire

Questionnaire Survey for Master Thesis on Assessment of the management and expansion of small holder pump irrigation in lower Gumara River.

Dear respondent; I would like to appreciate your willingness to participate in the current senior research study. The main objective of the research is Assessment of the management and expansion of small holder pump irrigation in lower Gumara River. I kindly request you to fill the entire questions with all information accurately, truthfully and honestly. I guarantee that all information you supply will be kept confidentially.

Zone.................................. Woreda................................ Kebele…........................ Enumerator Name...

1. Personal Information of Respondent

1.1 Name of respondent…………………………………

1.2 Sex A. Male B. Female

1.3 Age…………………….

1.4 Literacy level of the household

A. Illiterate B. Able to read and write only

C. Elementary D. High school complete

2. General overview

2.1 When the Gumara river small holder pump irrigation started at the previous? By what cause it started?

2.2 How many woredas and kebeles the Gumara river motorized pump irrigation cover?

2.3 How many command area cover the Gumara river small holder motor pump irrigation practice? (command area coverage)

2.4 Who developed the irrigation scheme?

A. community B. government C. NGO D. A&B E.A&C

2.5 Who is the owner of the scheme?

A. community B. government C. NGO D. A&B E. A&C

2.6 From what up to what season the irrigation is active? (irrigation period)

2.7 How looks like the current status of the irrigation? Is that expanded or declind from year to year? Is there any farmer who stop his or her irrigation work; by what case?

3. Management practices

3.1. How many hectares of your cultivated land is accessible for irrigation? ________

3.2. Do you irrigate all of your irrigable land? A. yes B. no

3.3. If not, why? (Circle as many as apply)

A. shortage of water B. low productivity

C. getting sufficient produce by rain feed agriculture D. Poor quality of irrigation

3.4 Who manages and control the irrigation water?

A. The community as a whole

B. Representatives of the community

C. DAs or Kebele administrators

D. Others (Specify)………………………………

3.5 For how long (years) you practiced motor pump irrigation? __________

3.6 What are the major agricultural crops you produce using irrigation? _________

3.7 Why do you prefer to grow such crops?

A. better price B. good production C. easy to operate

D. high disease tolerance E. seeds availability F. others (specify) _______

3.8 System of irrigation; A. Furrow B. Flooding C. Others

3.9 What criteria should you used to decide when to irrigated crops? Or how do you know your farm weather need or not need water?

A. Wait until see signs of wilting on the leaves

B. check the soil near the roots When it is dry, I irrigate

C. irrigate every day

3.10 Have you ever faced a problem of crop failure when using irrigation?

A. Yes B. No

3.11 If yes, why? (Circle as many as apply)

A. water shortage B. crop disease C. poor irrigation maintenance

D. over flooding of the farm and consequent erosion E. others (specify)

3.12 Are you able to apply as much water as you would like to your crops?

A. yes B. no

3.11 After how many days supply water for each crop?

4.13 How much each crop live on-farm from sawing up to harvesting? (cropping period)

3.14 Is that the Gumara river water enough for the pump irrigation purpose? If not by what case?

3.15 What type of change is happen on irrigation water year to year;

A. decrease B. Increase C. No change

3.16 Is there any farmer who uses ground water for irrigation purpose around this area? Why?

3.17 Is there any governmental or non-governmental project which use water from Gumara river?

4. Sources of disagreement and Resolution mechanisms

4.1 Is there disagreement between beneficiary in the irrigation? A. Yes B. No

4.2 If yes, what do you think is/are the common source(s) of disagreement?

4.3 Is water equally available to all users in the scheme? A. Yes B. No

4.4 Disagreement resolution methods

A. By law B. By Kebele Administration C. By elders

4.5 Do you for see any disagreement on the water use in the future? A. Yes B. No

If yes, what will be the causes? ....

4.6 What should be done to avoid the disagreement? ....

5. About motor pump and factors influencing the adoption

5.1 What types of motor pumps exist?

5.2 How many motor pumps exist at the previous 15 or 10 years; what about the current time?

5.3 Is that the number of pumps increase or decrease year to year? What about the number of motor pump users?

5.4 Why you became the user for motorized pump system? Why not use an other system?

5.5 What factors influencing the adoption of the motorized water pump for irrigation? Why not other farmers adopte or use the motorized water pumps for irrigation?

6. Availability of Credit

6.1 Do you use motorized water pump by buying in cash? A. Yes B. no

6.2 If the answer is “no” what is the reason?

A. Do not have cash   B. No access of credit

6.3 Have you ever received credit service for irrigation? A. Yes, B. no

6.4 What factors hinder for the access of credit? A. High interest rate B. No credit service for motorized water pump C. if other specify……………………..

7. Support services

7.1 Were there any organization which support or supervise you? A. yes   B. no

7.2 Do you have access to different input supply for irrigation? A. yes   B. no

7.3 Did you use improved seed, fertilizer, and hand tools?   A. yes   B. no

8. Extension and Training

8.1 Have you ever visited by an extension agent and get training? A. Yes   B. No

8.2 If yes, during which operation?

A. land preparation   B. planting/transplanting   C. weeding

D. applying agro chemicals   E. watering   F. harvesting

8.3 If No, why?

Generally what Problems and good things are observed from year to year?

What are the suggested solutions for the problems?

Appendix 2 Tables and Figures

Appendix Table 2-1 Gumara River monthly flow (m3/s)

Year/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	1.35	0.39	0.30	0.62	0.34	2.17	60.04	155.75	94.36	31.85	11.82	6.44
1981	1.45	0.60	0.40	0.21	0.90	1.31	31.11	121.51	104.30	33.57	9.53	4.76
1982	1.56	0.91	1.17	0.50	0.59	2.89	22.75	111.33	64.13	33.44	8.88	2.51
1983	2.25	1.52	0.91	0.53	0.72	2.19	29.56	139.18	58.28	18.99	8.25	2.90
1984	1.68	1.40	0.69	0.45	1.01	8.32	56.38	101.87	58.51	13.11	6.66	4.23
1985	1.70	1.29	0.49	0.57	1.49	3.12	118.50	132.53	114.42	26.98	13.80	8.24
1986	4.07	2.29	1.10	0.83	0.42	18.41	100.49	115.63	83.65	34.19	12.52	7.11
1987	1.59	0.97	0.65	0.44	3.33	14.65	34.20	126.58	42.69	10.22	4.78	2.04
1988	0.93	0.56	0.34	0.25	0.41	1.97	161.94	158.65	87.95	54.84	9.82	4.41
1989	2.13	1.13	0.61	0.52	0.84	10.57	87.63	144.93	65.42	22.47	15.72	4.92
1990	2.39	0.91	0.61	0.40	0.54	1.31	52.81	180.36	109.28	19.82	4.14	1.93
1991	1.01	0.53	0.38	0.44	0.81	14.22	83.22	168.09	76.81	23.43	4.76	4.79
1992	3.05	2.07	2.74	0.84	1.89	1.98	42.12	158.53	71.11	50.35	14.93	6.34
1993	2.70	1.31	0.70	0.91	2.12	10.37	85.92	140.16	100.44	37.67	11.71	4.74
1994	2.38	1.31	0.61	0.35	1.01	19.35	84.88	194.35	122.47	19.99	7.02	4.14
1995	2.16	1.67	1.48	1.39	1.56	4.99	61.61	148.57	98.55	24.95	17.02	12.74
1996	7.45	3.63	3.37	3.40	7.99	56.43	179.08	200.47	101.51	36.94	22.11	15.25
1997	10.78	7.99	6.63	4.97	7.35	48.03	141.98	150.53	79.62	58.90	54.58	16.69
1998	2.81	1.69	1.29	0.81	1.91	10.80	67.38	138.08	92.61	28.14	8.81	8.70
1999	6.79	1.72	0.75	0.56	0.74	5.00	71.48	97.54	52.79	59.75	13.01	7.07
2000	3.02	1.70	1.62	2.66	1.87	13.36	107.51	172.20	53.66	48.08	13.20	5.43
2001	3.18	1.97	1.76	1.34	1.83	14.29	90.97	196.18	56.72	13.76	5.98	3.73
2002	2.84	2.05	2.02	1.74	1.21	23.28	89.93	153.00	78.71	12.41	6.88	5.22
2003	3.88	3.16	3.20	2.42	2.29	14.13	88.23	171.74	153.65	45.89	8.07	5.16
2004	3.81	3.24	2.66	3.09	2.49	9.46	77.13	104.72	52.67	20.53	8.19	5.45
2005	4.02	3.30	3.63	2.63	3.45	13.93	75.30	119.49	129.77	40.01	9.04	5.88
2006	4.28	3.49	3.32	3.28	6.59	17.34	88.99	213.63	142.39	24.36	9.52	5.79
2007	3.91	1.98	1.62	1.31	2.68	44.20	114.49	145.94	169.87	29.86	9.43	6.16
2008	3.21	1.98	2.17	4.74	6.62	39.10	158.11	229.45	106.92	13.75	11.64	6.21
2009	3.21	1.98	1.62	1.31	2.10	3.87	108.32	204.75	87.44	11.99	5.35	3.14
2010	2.72	2.69	1.83	1.96	5.23	19.09	161.89	181.54	130.76	28.08	7.26	5.16
2011	3.82	3.02	2.73	2.52	3.94	9.04	99.51	182.65	142.41	39.29	15.44	6.71
2012	4.71	3.97	3.31	3.03	3.70	28.00	134.66	167.21	120.88	27.83	15.14	6.98
2013	4.93	4.12	2.58	3.33	4.75	10.98	148.58	168.45	103.63	87.32	16.99	17.99
2014	11.20	7.36	10.72	7.72	27.14	46.05	149.33	220.70	164.55	99.39	19.35	18.13
Average	3.51	2.28	2.00	1.77	3.20	15.55	93.31	157.61	96.37	33.78	12.04	6.77

Appendix Table 2-2 Average (2001-2017) meteorological data

Stations	Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Wanzaye													
2001-2017	RF (mm)	3.6	1.1	8.2	33.5	98.8	172.9	413.5	419.1	210.5	72.3	13.1	2.1
2001-2017	Tmin (^{o}C)	10.6	12.0	14.2	15.1	15.2	14.8	14.4	14.3	13.8	13.3	11.2	10.1
2001-2017	Tmax (^{o}C)	28.5	30.8	31.7	31.9	30.3	28.4	24.9	24.7	25.9	28.1	28.3	28.5
Bahir Dar													
2001-2017	RH	49	44	42	41	53	66	77	78	73	64	56	52
2001-2017	WS (m/s)	0.8	0.8	1.0	1.2	1.0	1.0	0.8	0.7	0.7	0.8	0.8	0.7
2001-2017	SS	9.6	9.6	9.2	9.2	8.3	6.9	4.8	4.5	6.3	8.8	9.5	9.7

Appendix Table 2-3 Meteorological data and ETo of the study area

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

Country: Ethiopia Station: Wanzaye

Altitude: 1800 m. Latitude: 13.00 °N Longitude: 35.00 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	10.6	28.5	49	1	9.6	20.6	3.06
February	12.0	30.8	44	1	9.6	22.2	3.49
March	14.2	31.7	42	1	9.2	23.1	3.90
April	15.1	31.9	41	1	9.2	23.7	4.17
May	15.2	30.3	53	1	8.3	22.1	4.08
June	14.8	28.4	66	1	6.9	19.7	3.76
July	14.4	24.9	77	1	4.8	16.6	3.19
August	14.3	24.7	78	1	4.5	16.3	3.08
September	13.8	25.9	73	1	6.3	18.7	3.39
October	13.3	28.1	64	1	8.8	21.3	3.67
November	11.2	28.3	56	1	9.5	20.7	3.28
December	10.1	28.5	52	1	9.7	20.1	3.00
Average	**13.3**	**28.5**	**58**	**1**	**8.0**	**20.4**	**3.51**

Appendix Table 2-4 Rainfall and Eff.rain of Wanzaye station

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

Station: Wanzaye   Eff. rain method: FAO/AGLW formula

	Rain	Eff rain
	mm	mm
January	3.6	0.0
February	1.1	0.0
March	8.2	0.0
April	33.5	10.1
May	98.8	55.0
June	172.9	114.3
July	413.5	306.8
August	419.1	311.3
September	210.5	144.4
October	72.3	33.8
November	13.1	0.0
December	2.1	0.0
Total	1448.7	975.8

Appendix Table 2-5 Summary of crop data for the major crops

Crops	Planting date	Total growing period	K_C				Root depth (m)		Crop max.ht (m)
			Initial	Dev't	Mid	Late	Initial	Late	
Onion	01/11	120	25	50	30	15	0.3	0.6	0.40
			0.70		1.05	0.75			
Tomato	15/11	110	25	30	35	20	0.25	1.00	0.60
			0.60		1.15	0.80			
Potato	15/11	115	20	30	35	30	0.30	0.60	0.60
			0.50		1.15	0.75			
Maize	01/03	120	20	35	40	25	0.30	1.00	2.00
			0.30		1.20	0.35			

Source: CROPWAT data base and FAO tables (Allen et al., 1998) with relate the interview

Appendix Table 2-6 Summary of soil data

Soil - C:\ProgramData\CROPWAT\data\soils\BLACK CLAY SOIL.SOI

Soil name: BLACK CLAY SOIL

General soil data

Total available soil moisture (FC - WP)	200.0	mm/meter
Maximum rain infiltration rate	30	mm/day
Maximum rooting depth		centimeters
Initial soil moisture depletion (as % TAM)	50	%
Initial available soil moisture	100.0	mm/meter

Appendix Table 2-7 Crop water requirements (CWR) for selected crops

Onion

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.7	2.39	23.9	0.1	23.8
Nov	2	Init	0.7	2.3	23	0	23
Nov	3	Deve	0.71	2.26	22.6	0	22.6
Dec	1	Deve	0.77	2.38	23.8	0	23.8
Dec	2	Deve	0.84	2.51	25.1	0	25.1
Dec	3	Deve	0.91	2.74	30.1	0	30.1
Jan	1	Deve	0.98	2.97	29.7	0	29.7
Jan	2	Mid	1.03	3.15	31.5	0	31.5
Jan	3	Mid	1.03	3.31	36.4	0	36.4
Feb	1	Mid	1.03	3.46	34.6	0	34.6
Feb	2	Late	0.98	3.41	34.1	0	34.1
Feb	3	Late	0.81	2.92	23.4	0	23.4
					338.2	0.1	338.1

Tomato

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	2	Init	0.6	1.97	11.8	0	11.8
Nov	3	Init	0.6	1.91	19.1	0	19.1
Dec	1	Deve	0.6	1.86	18.6	0	18.6
Dec	2	Deve	0.72	2.14	21.4	0	21.4
Dec	3	Deve	0.9	2.72	29.9	0	29.9
Jan	1	Mid	1.08	3.29	32.9	0	32.9
Jan	2	Mid	1.13	3.46	34.6	0	34.6
Jan	3	Mid	1.13	3.62	39.9	0	39.9
Feb	1	Mid	1.13	3.79	37.9	0	37.9
Feb	2	Late	1.07	3.73	37.3	0	37.3
Feb	3	Late	0.91	3.31	26.5	0	26.5
Mar	1	Late	0.81	3.04	12.2	0	12.2
					322.1	0	322.1

Potato

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	2	Init	0.5	1.64	9.8	0	9.8
Nov	3	Init	0.5	1.59	15.9	0	15.9
Dec	1	Deve	0.54	1.68	16.8	0	16.8
Dec	2	Deve	0.74	2.23	22.3	0	22.3
Dec	3	Deve	0.96	2.91	32	0	32
Jan	1	Mid	1.13	3.42	34.2	0	34.2
Jan	2	Mid	1.13	3.46	34.6	0	34.6
Jan	3	Mid	1.13	3.62	39.9	0	39.9
Feb	1	Late	1.12	3.76	37.6	0	37.6
Feb	2	Late	1.02	3.55	35.5	0	35.5
Feb	3	Late	0.9	3.26	26.1	0	26.1
Mar	1	Late	0.79	2.95	26.6	0	26.6
					331.3	0	331.3

Maize

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Mar	1	Init	0.3	1.13	11.3	0	11.3
Mar	2	Init	0.3	1.17	11.7	0	11.7
Mar	3	Deve	0.45	1.78	19.6	0.1	19.4
Apr	1	Deve	0.7	2.85	28.5	1.2	27.4
Apr	2	Deve	0.94	3.93	39.3	1.8	37.5
Apr	3	Mid	1.13	4.69	46.9	7.3	39.6
May	1	Mid	1.15	4.72	47.2	12.9	34.2
May	2	Mid	1.15	4.68	46.8	17.7	29.1
May	3	Mid	1.15	4.56	50.2	24.5	25.7
Jun	1	Late	1.06	4.09	40.9	27.3	13.6
Jun	2	Late	0.75	2.82	28.2	31.8	0
Jun	3	Late	0.46	1.65	13.2	44.2	0
					383.7	168.8	249.5

Appendix Table 2-8 Percentage area coverage for selected crops

crops	area (ha)	(%)
onion	3275.75	83
Tomato	531.75	13
potato	135.625	3
Maize	3221.25	82
Total	3943.125	99

Source: From interview

Appendix Table 2-9 Monthly basis demand calculation for selected crop

	Crop demand (mm/month)			
Month	Onion	Tomato	Potato	Maize
Nov	69.4	30.9	25.7	
Dec	79	69.9	71.1	
Jan	97.6	107.4	108.7	
Feb	92.1	101.7	99.2	
Mar		12.2	26.6	42.4
Apr				104.5
May				89
Jun				13.6

	Onion			2017		2010		2001	
Month	(mm/ month)	m/ month	%	(m^2)	m^3	m^2	m^3	m^2	m^3
Nov	69.4	0.0694	0.83	23077100	1329287.11	13074500	753117	3228200	185950.78
Dec	79	0.079	0.83	23077100	1513165.45	13074500	857295	3228200	211673.07
Jan	97.6	0.0976	0.83	23077100	1869429.72	13074500	1059139	3228200	261510.03
Feb	92.1	0.0921	0.83	23077100	1764082.76	13074500	999454	3228200	246773.29

	Tomato			2017		2010		2001	
Month	(mm/ month)	m/ month	%	(m^2)	m^3	m^2	m^3	m^2	m^3
Nov	30.9	0.0309	0.13	23077100	92700.71	13074500	52520.27	3228200	12967.68
Dec	69.9	0.0699	0.13	23077100	209701.61	13074500	118808	3228200	29334.65
Jan	107.4	0.1074	0.13	23077100	322202.47	13074500	182546.2	3228200	45072.13
Feb	101.7	0.1017	0.13	23077100	305102.34	13074500	172858	3228200	42680.03
Mar	12.2	0.0122	0.13	23077100	36600.28	13074500	20736.16	3228200	5119.93

	Potato			2017		2010		2001	
Month	(mm/ month)	m/ month	%	(m^2)	m^3	m^2	m^3	m^2	m^3
Nov	25.7	0.0257	0.03	23077100	17792.44	13074500	10080.44	3228200	2488.94
Dec	71.1	0.0711	0.03	23077100	49223.45	13074500	27887.91	3228200	6885.75
Jan	108.7	0.1087	0.03	23077100	75254.42	13074500	42635.94	3228200	10527.16
Feb	99.2	0.0992	0.03	23077100	68677.45	13074500	38909.71	3228200	9607.12
Mar	26.6	0.0266	0.03	23077100	18415.53	13074500	10433.45	3228200	2576.10

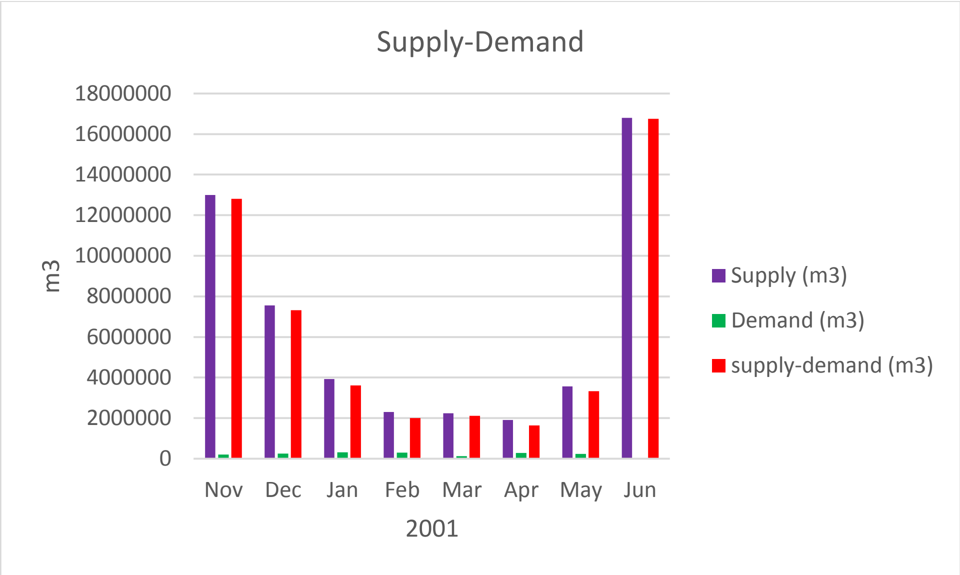
	Maize			2017		2010		2001	
Month	(mm/ month)	m/ month	%	(m^2)	m^3	m^2	m^3	m^2	m^3
Mar	42.4	0.0424	0.82	23077100	802344.61	13074500	454574	3228200	112238.06
Apr	104.5	0.1045	0.82	23077100	1977476.70	13074500	1120354	3228200	276624.46
May	89	0.089	0.82	23077100	1684166.76	13074500	954177	3228200	235594.04
Jun	13.6	0.0136	0.82	23077100	257355.82	13074500	145807	3228200	36000.89

Appendix Table 2-10 Average monthly irrigation Supply

Month	Flow (m^3/s)	each month (days)	10hr/day	Supply (m^3/irrn.)
Nov	12.038	30	36000	13000619.06
Dec	6.774	31	36000	7559533.58
Jan	3.514	31	36000	3921403.76
Feb	2.283	28	36000	2301305.10
Mar	2.000	31	36000	2232189.80
Apr	1.773	30	36000	1915009.78
May	3.196	31	36000	3567235.29
Jun	15.548	30	36000	16791939.53

Appendix Table 2-11 Supply-Demand for the years 2001

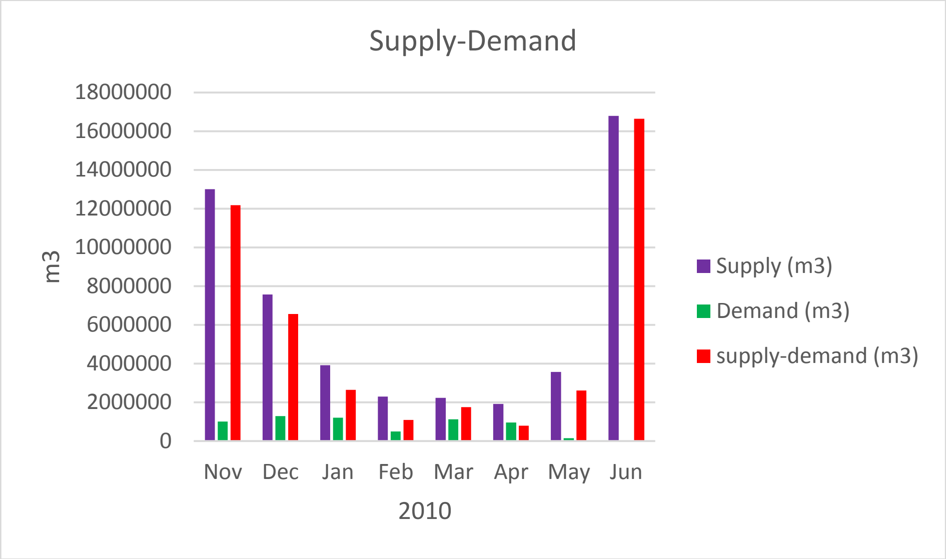
		2001	
Month	Supply (m^3)	Demand (m^3)	supply-demand (m^3)
Nov	13000619.06	201407.398	12799211.67
Dec	7559533.577	247893.478	7311640.099
Jan	3921403.763	317109.3142	3604294.448
Feb	2301305.102	299060.448	2002244.654
Mar	2232189.796	119934.0864	2112255.709
Apr	1915009.781	276624.458	1638385.323
May	3567235.292	235594.036	3331641.256
Jun	16791939.53	36000.8864	16755938.65



Appendix Figure 2-1 Supply-Demand of 2001

Appendix Table 2-12 Supply-Demand for the years 2010

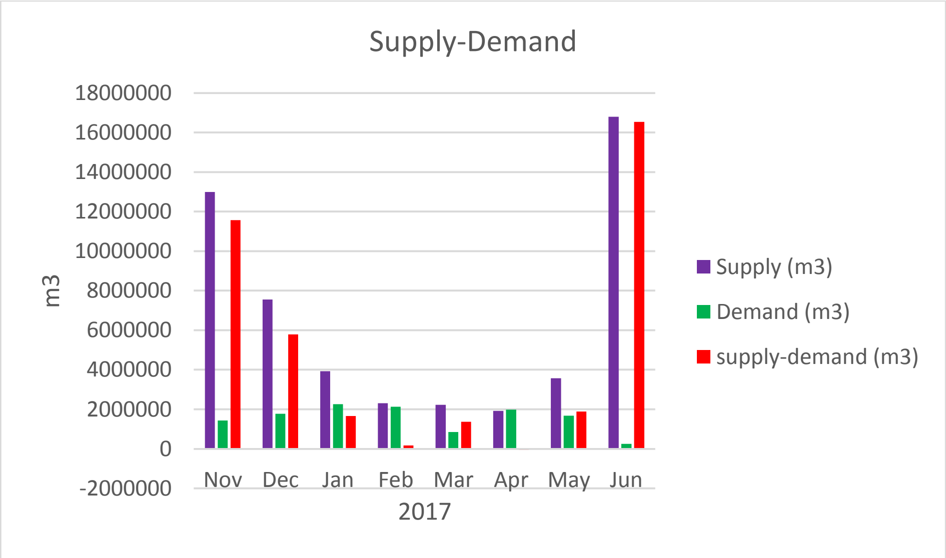
		2010	
Month	Supply (m^3)	Demand (m^3)	supply-demand (m^3)
Nov	13000619.06	815718.055	12184901.01
Dec	7559533.577	1003990.855	6555542.722
Jan	3921403.763	1284321.21	2637082.553
Feb	2301305.102	1211221.68	1090083.422
Mar	2232189.796	485743.824	1746445.972
Apr	1915009.781	1120353.905	794655.8756
May	3567235.292	954177.01	2613058.282
Jun	16791939.53	145806.824	16646132.71



Appendix Figure 2-2 Supply-Demand of 2010

Appendix Table 2-13 Supply-Demand for the years 2017

		2017	
Month	Supply (m^3)	Demand (m^3)	supply-demand (m^3)
Nov	13000619.06	1439780.269	11560838.8
Dec	7559533.577	1772090.509	5787443.068
Jan	3921403.763	2266886.61	1654517.152
Feb	2301305.102	2137862.544	163442.5583
Mar	2232189.796	857360.4192	1374829.377
Apr	1915009.781	1977476.699	-62466.91843
May	3567235.292	1684166.758	1883068.534
Jun	16791939.53	257355.8192	16534583.71



Appendix Figure 2-3 Supply-Demand of 2017

Appendix Table 2-14 GCP for shape extraction and land cover classification

	Ground control Points			
FID	Shape*	Easting	Northing	Class type
1	point	358864	1302025	Irrigated agricultural land
2	point	358372	1301998	Irrigated agricultural land
3	point	358922	1302231	Irrigated agricultural land
4	point	358573	1302242	Irrigated agricultural land
5	point	358224	1302268	Irrigated agricultural land
6	point	358112	1302528	Irrigated agricultural land
7	point	357769	1302946	Irrigated agricultural land
8	point	357652	1303104	Irrigated agricultural land
9	point	357028	1302972	Irrigated agricultural land
10	point	356715	1303268	Irrigated agricultural land
11	point	356668	1303126	Irrigated agricultural land
12	point	351731	1311529	Irrigated agricultural land
13	point	351408	1311667	Irrigated agricultural land
14	point	351413	1312037	Irrigated agricultural land
15	point	351085	1311741	Irrigated agricultural land
16	point	350715	1312143	Irrigated agricultural land
17	point	350646	1312043	Irrigated agricultural land
18	point	350492	1311926	Irrigated agricultural land
19	point	350350	1311963	Irrigated agricultural land
20	point	349984	1311905	Irrigated agricultural land
21	point	350037	1312016	Irrigated agricultural land
22	point	349603	1312069	Irrigated agricultural land
23	point	348795	1313078	Irrigated agricultural land
24	point	348639	1313171	Irrigated agricultural land
25	point	348504	1313019	Irrigated agricultural land
26	point	348487	1312929	Irrigated agricultural land
27	point	348189	1313078	Irrigated agricultural land
28	point	348110	1313118	Irrigated agricultural land
29	point	345786	1314213	Irrigated agricultural land
30	point	345300	1314197	Irrigated agricultural land
31	point	345194	1314054	Irrigated agricultural land
32	point	345270	1313917	Irrigated agricultural land
33	point	345612	1314473	Irrigated agricultural land
34	point	343763	1313186	Irrigated agricultural land
35	point	343922	1312838	Irrigated agricultural land
36	point	347254	1313716	Irrigated agricultural land
37	point	347019	1313572	Irrigated agricultural land
38	point	346919	1313610	Irrigated agricultural land
39	point	343819	1312762	Irrigated agricultural land
40	point	343763	1312610	Irrigated agricultural land
41	point	343508	1312981	Irrigated agricultural land
42	point	343455	1312795	Irrigated agricultural land
43	point	343330	1312742	Irrigated agricultural land
44	point	343244	1312623	Irrigated agricultural land
45	point	343148	1312362	Irrigated agricultural land
46	point	343088	1312316	Irrigated agricultural land

47	point	345286	1314189	Irrigated agricultural land
48	point	345176	1314081	Irrigated agricultural land
49	point	345037	1313816	Irrigated agricultural land
50	point	340988	1312104	Irrigated agricultural land
51	point	341226	1312065	Irrigated agricultural land
52	point	341306	1312766	Irrigated agricultural land
53	point	341219	1313242	Irrigated agricultural land
54	point	340784	1312528	Irrigated agricultural land
55	point	339805	1313948	Irrigated agricultural land
56	point	339623	1314001	Irrigated agricultural land
57	point	339220	1313733	Irrigated agricultural land
58	point	339008	1313945	Irrigated agricultural land
59	point	336501	1316208	Irrigated agricultural land
60	point	336425	1316155	Irrigated agricultural land
61	point	336319	1316095	Irrigated agricultural land
62	point	336400	1315970	Irrigated agricultural land
63	point	336656	1315939	Irrigated agricultural land
64	point	336735	1316093	Irrigated agricultural land
65	point	337018	1315871	Irrigated agricultural land
66	point	336757	1315738	Irrigated agricultural land
67	point	336894	1315599	Irrigated agricultural land
68	point	336972	1315908	Irrigated agricultural land
69	point	337114	1315793	Irrigated agricultural land
70	point	337402	1315326	Irrigated agricultural land
71	point	337593	1315237	Irrigated agricultural land
72	point	337955	1314977	Irrigated agricultural land
73	point	338082	1314875	Irrigated agricultural land
74	point	338266	1314805	Irrigated agricultural land
75	point	338241	1314678	Irrigated agricultural land
76	point	338552	1314767	Irrigated agricultural land
77	point	339605	1313917	Irrigated agricultural land
78	point	339864	1313868	Irrigated agricultural land
79	point	339938	1313591	Irrigated agricultural land
80	point	358710	1302760	Non-irrigated agricultural land
81	point	358678	1303279	Non-irrigated agricultural land
82	point	358588	1303490	Non-irrigated agricultural land
83	point	358435	1303771	Non-irrigated agricultural land
84	point	358398	1303929	Non-irrigated agricultural land
85	point	358181	1303850	Non-irrigated agricultural land
86	point	357826	1303797	Non-irrigated agricultural land
87	point	357599	1303808	Non-irrigated agricultural land
88	point	357212	1303824	Non-irrigated agricultural land
89	point	355759	1303885	Non-irrigated agricultural land
90	point	355346	1304133	Non-irrigated agricultural land
91	point	355187	1304418	Non-irrigated agricultural land
92	point	354463	1305349	Non-irrigated agricultural land
93	point	354362	1305273	Non-irrigated agricultural land
94	point	353586	1307242	Non-irrigated agricultural land
95	point	353459	1307377	Non-irrigated agricultural land

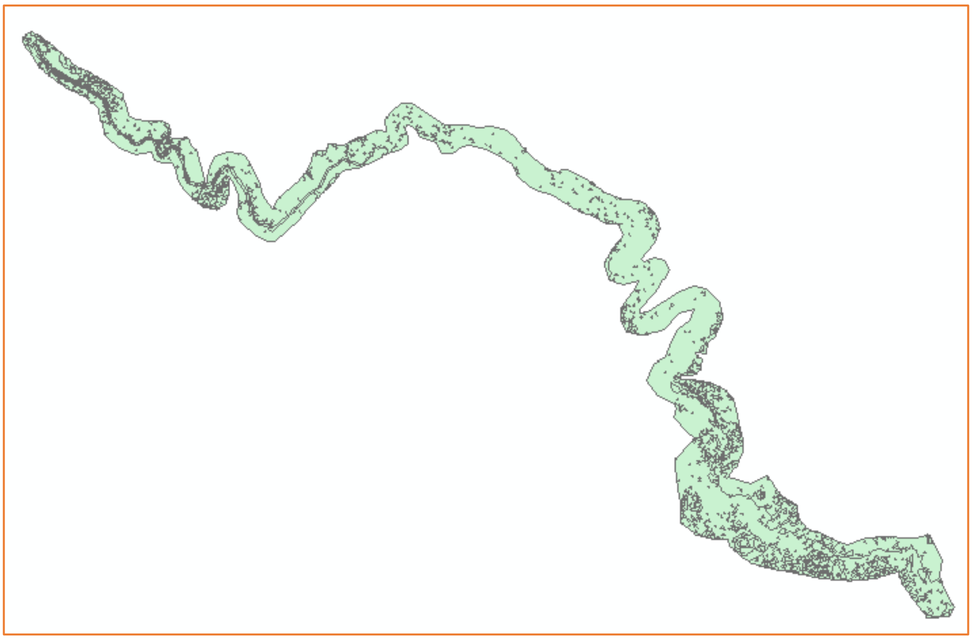
96	point	352565	1307651	Non-irrigated agricultural land
97	point	353356	1309332	Non-irrigated agricultural land
98	point	353267	1309580	Non-irrigated agricultural land
99	point	353105	1309791	Non-irrigated agricultural land
100	point	353000	1309872	Non-irrigated agricultural land
101	point	352952	1309936	Non-irrigated agricultural land
102	point	352806	1309971	Non-irrigated agricultural land
103	point	352900	1309722	Non-irrigated agricultural land
104	point	351222	1308991	Non-irrigated agricultural land
105	point	351088	1309028	Non-irrigated agricultural land
106	point	350986	1309015	Non-irrigated agricultural land
107	point	350571	1310430	Non-irrigated agricultural land
108	point	350496	1310515	Non-irrigated agricultural land
109	point	351619	1311840	Non-irrigated agricultural land
110	point	351475	1311873	Non-irrigated agricultural land
111	point	351052	1312004	Non-irrigated agricultural land
112	point	350515	1312267	Non-irrigated agricultural land
113	point	350239	1312227	Non-irrigated agricultural land
114	point	350144	1312403	Non-irrigated agricultural land
115	point	350179	1312556	Non-irrigated agricultural land
116	point	349519	1312816	Non-irrigated agricultural land
117	point	349304	1312318	Non-irrigated agricultural land
118	point	346341	1314116	Non-irrigated agricultural land
119	point	346232	1314134	Non-irrigated agricultural land
120	point	346129	1314263	Non-irrigated agricultural land
121	point	345405	1314351	Non-irrigated agricultural land
122	point	344303	1313521	Non-irrigated agricultural land
123	point	343747	1313492	Non-irrigated agricultural land
124	point	343456	1313272	Non-irrigated agricultural land
125	point	342762	1312347	Non-irrigated agricultural land
126	point	342558	1312158	Non-irrigated agricultural land
127	point	341161	1313214	Non-irrigated agricultural land
128	point	340923	1313008	Non-irrigated agricultural land
129	point	340541	1313255	Non-irrigated agricultural land
130	point	339044	1313788	Non-irrigated agricultural land
131	point	338862	1313977	Non-irrigated agricultural land
132	point	338863	1314285	Non-irrigated agricultural land
133	point	338717	1314242	Non-irrigated agricultural land
134	point	338649	1314632	Non-irrigated agricultural land
135	point	337547	1315419	Non-irrigated agricultural land
136	point	337209	1315625	Non-irrigated agricultural land
137	point	336836	1315614	Non-irrigated agricultural land
138	point	336738	1315674	Non-irrigated agricultural land
139	point	336619	1316094	Non-irrigated agricultural land
140	point	336439	1316033	Non-irrigated agricultural land
141	point	336320	1316057	Non-irrigated agricultural land
142	point	336408	1315841	Non-irrigated agricultural land
143	point	337760	1314952	Non-irrigated agricultural land
144	point	336723	1315533	Non-irrigated agricultural land

145	point	336472	1315793	Non-irrigated agricultural land
146	point	336582	1315580	Non-irrigated agricultural land
147	point	336712	1315516	Non-irrigated agricultural land
148	point	336680	1316149	Non-irrigated agricultural land
149	point	336830	1315762	Non-irrigated agricultural land
150	point	355914	1303044	Forest/shrubs
151	point	355837	1303113	Forest/shrubs
152	point	355815	1303041	Forest/shrubs
153	point	355755	1303014	Forest/shrubs
154	point	355727	1302984	Forest/shrubs
155	point	355847	1303196	Forest/shrubs
156	point	355773	1303468	Forest/shrubs
157	point	354323	1304900	Forest/shrubs
158	point	354139	1304661	Forest/shrubs
159	point	353624	1303943	Forest/shrubs
160	point	353469	1303950	Forest/shrubs
161	point	352338	1305009	Forest/shrubs
162	point	352312	1305114	Forest/shrubs
163	point	352278	1305410	Forest/shrubs
164	point	351718	1307493	Forest/shrubs
165	point	351649	1307584	Forest/shrubs
166	point	351776	1307601	Forest/shrubs
167	point	351561	1307713	Forest/shrubs
168	point	351500	1310844	Forest/shrubs
169	point	351415	1310749	Forest/shrubs
170	point	351495	1310970	Forest/shrubs
171	point	351254	1310979	Forest/shrubs
172	point	351490	1311990	Forest/shrubs
173	point	351790	1311332	Forest/shrubs
174	point	351687	1311324	Forest/shrubs
175	point	351326	1311644	Forest/shrubs
176	point	351351	1311764	Forest/shrubs
177	point	351525	1311983	Forest/shrubs
178	point	350954	1311315	Forest/shrubs
179	point	351016	1311289	Forest/shrubs
180	point	348164	1313461	Forest/shrubs
181	point	348060	1313489	Forest/shrubs
182	point	347964	1313668	Forest/shrubs
183	point	345549	1314435	Forest/shrubs
184	point	345494	1314416	Forest/shrubs
185	point	345166	1313901	Forest/shrubs
186	point	341803	1311653	Forest/shrubs
187	point	339089	1313814	Forest/shrubs
188	point	339012	1313870	Forest/shrubs
189	point	339006	1313809	Forest/shrubs
190	point	338988	1314057	Forest/shrubs
191	point	338569	1313928	Forest/shrubs
192	point	338535	1313961	Forest/shrubs
193	point	338475	1314024	Forest/shrubs

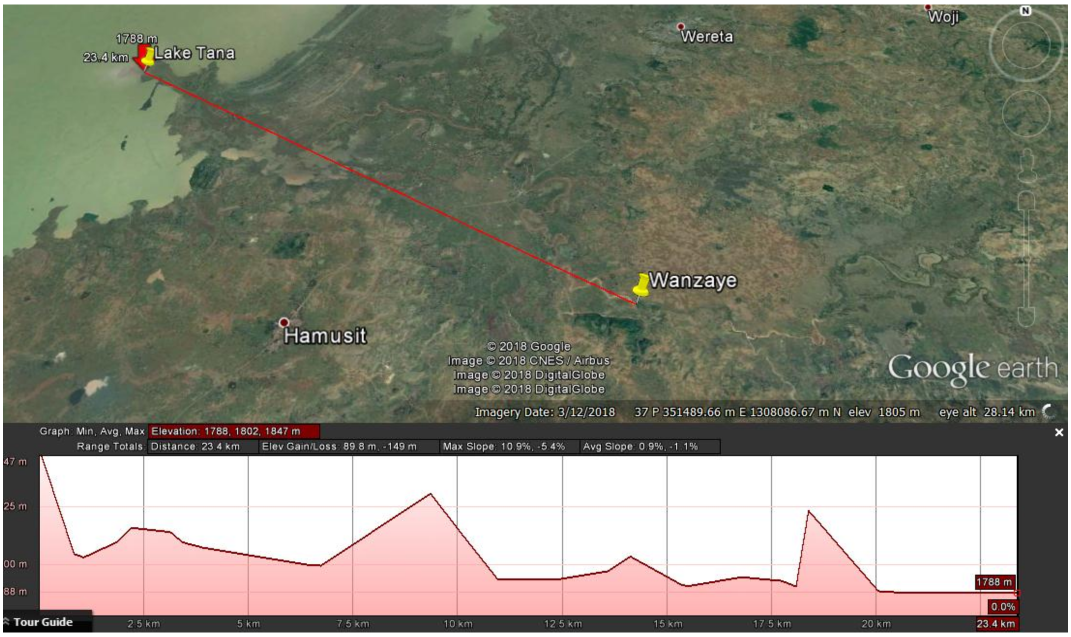
194	point	338387	1314411	Forest/shrubs
195	point	338501	1314564	Forest/shrubs
196	point	338207	1314652	Forest/shrubs
197	point	338084	1314708	Forest/shrubs
198	point	337090	1315255	Forest/shrubs
199	point	337249	1315614	Forest/shrubs
200	point	336826	1315551	Forest/shrubs
201	point	336799	1315768	Forest/shrubs
202	point	336648	1315791	Forest/shrubs
203	point	336585	1315823	Forest/shrubs
204	point	336796	1315977	Forest/shrubs
205	point	336559	1315913	Forest/shrubs
206	point	336494	1316012	Forest/shrubs
207	point	336467	1316030	Forest/shrubs
208	point	336438	1316057	Forest/shrubs
209	point	336527	1316018	Forest/shrubs
210	point	336436	1316068	Forest/shrubs
211	point	336564	1316068	Forest/shrubs
212	point	336463	1315759	Forest/shrubs
213	point	339046	1313281	Forest/shrubs
214	point	339218	1313293	Forest/shrubs
215	point	339193	1313511	Forest/shrubs
216	point	358753	1302694	Flooded agricultural land
217	point	358823	1302571	Flooded agricultural land
218	point	358729	1302531	Flooded agricultural land
219	point	358719	1302384	Flooded agricultural land
220	point	352816	1308561	Flooded agricultural land
221	point	350776	1311685	Flooded agricultural land
222	point	349815	1312369	Flooded agricultural land
223	point	349336	1312191	Flooded agricultural land
224	point	349547	1312793	Flooded agricultural land
225	point	349003	1312492	Flooded agricultural land
226	point	348997	1312382	Flooded agricultural land
227	point	348612	1312485	Flooded agricultural land
228	point	348647	1312526	Flooded agricultural land
229	point	348587	1312614	Flooded agricultural land
230	point	348436	1312703	Flooded agricultural land
231	point	348525	1312882	Flooded agricultural land
232	point	348344	1313305	Flooded agricultural land
233	point	347356	1313599	Flooded agricultural land
234	point	347067	1313412	Flooded agricultural land
235	point	346888	1313321	Flooded agricultural land
236	point	346758	1313393	Flooded agricultural land
237	point	346607	1313453	Flooded agricultural land
238	point	346517	1313331	Flooded agricultural land
239	point	346487	1313634	Flooded agricultural land
240	point	346363	1313603	Flooded agricultural land
241	point	346152	1313663	Flooded agricultural land
242	point	346214	1313995	Flooded agricultural land

243	point	346098	1314292	Flooded agricultural land
244	point	345915	1314292	Flooded agricultural land
245	point	345664	1314156	Flooded agricultural land
246	point	345374	1314323	Flooded agricultural land
247	point	345494	1314014	Flooded agricultural land
248	point	344778	1313694	Flooded agricultural land
249	point	344931	1313571	Flooded agricultural land
250	point	344358	1312881	Flooded agricultural land
251	point	341778	1313078	Flooded agricultural land
252	point	341709	1312941	Flooded agricultural land
253	point	341626	1313247	Flooded agricultural land
254	point	341555	1313236	Flooded agricultural land
255	point	341443	1313194	Flooded agricultural land
256	point	340996	1313092	Flooded agricultural land
257	point	340580	1313169	Flooded agricultural land
258	point	338746	1314657	Flooded agricultural land
259	point	338597	1314679	Flooded agricultural land
260	point	337125	1315550	Flooded agricultural land
261	point	337079	1315828	Flooded agricultural land
262	point	336854	1315767	Flooded agricultural land
263	point	336616	1316033	Flooded agricultural land
264	point	336389	1316122	Flooded agricultural land
265	point	336496	1316039	Flooded agricultural land
266	point	336495	1315973	Flooded agricultural land
267	point	336671	1315774	Flooded agricultural land
268	point	336584	1315718	Flooded agricultural land
269	point	337064	1315301	Flooded agricultural land
270	point	344207	1313119	Flooded agricultural land
271	point	344118	1313119	Flooded agricultural land
272	point	344191	1312976	Flooded agricultural land
273	point	344628	1313014	Flooded agricultural land
274	point	345412	1313419	Flooded agricultural land
275	point	338296	1314539	Flooded agricultural land
276	point	338177	1314698	Flooded agricultural land
277	point	338115	1314716	Flooded agricultural land
278	point	338084	1314746	Flooded agricultural land
279	point	337655	1315019	Flooded agricultural land
280	point	337815	1314988	Flooded agricultural land
281	point	338272	1314620	Flooded agricultural land
282	point	345647	1314158	Flooded agricultural land
283	point	345583	1314142	Flooded agricultural land
284	point	345702	1314106	Flooded agricultural land
285	point	345436	1313425	Flooded agricultural land
286	point	345396	1313428	Flooded agricultural land
287	point	345265	1313332	Flooded agricultural land
288	point	341827	1311954	Flooded agricultural land
289	point	341869	1311908	Flooded agricultural land
290	point	342963	1311932	Flooded agricultural land
291	point	342924	1311882	Flooded agricultural land

292	point	342848	1311812	Flooded agricultural land
293	point	342832	1311709	Flooded agricultural land
294	point	342725	1311663	Flooded agricultural land
295	point	342403	1311770	Flooded agricultural land
296	point	342307	1311778	Flooded agricultural land
297	point	341621	1312490	Flooded agricultural land
298	point	341587	1312576	Flooded agricultural land
299	point	341045	1312703	Flooded agricultural land
300	point	340486	1312502	Flooded agricultural land
301	point	340318	1312804	Flooded agricultural land
302	point	339683	1313209	Flooded agricultural land
303	point	339597	1313371	Flooded agricultural land
304	point	338882	1313589	Flooded agricultural land
305	point	337969	1314799	Flooded agricultural land
306	point	337899	1314865	Flooded agricultural land
307	point	337820	1314918	Flooded agricultural land
308	point	337114	1315264	Flooded agricultural land
309	point	336922	1315428	Flooded agricultural land
310	point	336899	1315485	Flooded agricultural land
311	point	336850	1315622	Flooded agricultural land
312	point	336662	1315778	Flooded agricultural land
313	point	336632	1315776	Flooded agricultural land
314	point	336526	1315942	Flooded agricultural land
315	point	336509	1315960	Flooded agricultural land
316	point	336418	1316115	Flooded agricultural land
317	point	336364	1316134	Flooded agricultural land



Appendix Figure 2-4 Raster extraction indication of Study area from GIS



Appendix Figure 2-5 Gumara River and study area from Google earth