JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCE AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

GEOSPATIAL ASSESSMENT OF SURFACE WATER IRRIGATION POTENTIAL USING GEOSPATIAL TECHNOLOGY:THE CASE OF ABA ALEMU WATERSHED , BARO-AKOBO RIVER BASIN, ETHIOPIA.

BY: TILAHUN ALI

THESIS SUBMITTED TO DEPARTMENT OF GEOGRAPHY AND ENVIRONMEN TAL STUDIES, SCHOOL OF GRADUATED STUDIES, JIMMA UNIVERSITY IN PARTIAL FULFILLMENTES OF THE REQUIRMENTS FOR THE DEGREE OF MASTER SCIENCES IN GIS AND REMOTE SENSING.

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APPROVAL PAGE

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Abstract

This study was conducted in Abaalemu watershed, Baro-Akobo river basin. The objective of the study was to assess the level of suitability and potential of the watershed for surface irrigation by using integrated approach that includes Geographic Information System (GIS) and Remote Sensing (RS). To identify suitable land for surface irrigation the physical land suitability parameters were used; such as slope, soil depth, texture, and land use land cover and drainage. After that they were reclassified by using Arc GIS spatial analyst (re-class) tools based on their suitability level and each parameters analyze individually by Geospatial analyst tools. After reclassification process, weight was assigned for each criteria using multi-criteria evaluation method using AHP procedures developed. Afterwards, all the standardized criteria were combined to perform weighted overlay analysis using Arc GIS spatial analyst (overlay) tools and thematic maps showing potential suitable site for irrigation were prepared. The result of the weight overlay analysis revealed that out of the total area that is 4786 ha, 254 ha (5.30 %) of the study area is found to be highly suitable for surface irrigation potential because it fulfill the environmental and socio economic criteria. In addition, 3746 ha (78.78 %) of the study area is moderately suitable for surface irrigation and about 583 ha (12.18 %) of the study area are found to be less suitable but the remaining of the study area which is 203 ha (4.27 %) is permanently not suitable for irrigation because this area is built up area. Generally above 80 % of the study area is suitable for surface irrigation. Therefore in order to gain additional suitable land for surface irrigation potential in the study area other suitability factors like chemical properties of soil, water quality, environmental, economic and social terms should be assessed to get a reliable result.

Key words: *Abaalemu watershed, ArcGIS, Remote sensing, Land suitability, Surface irrigation potential.*

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LIST OF ABBREVIATION AND ACRONYMS

AHP	Analytical Hierarchy Process
BMC	Billion Metric Cubes
CSA	Central Statistical Agency
DEM	Digital Elevation Model
LULC	Land Use Land cover
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resource Data Analysis System
FAOSTAT	Food and Agricultural Organization of Statistics
FAO	Food and Agricultural Organization
GIS	Geographical Information System:
GLAN	Global Land Cover Network
GPS	Global Positioning System
IWMI	International Water Management Institution
LULC	Land use Land Cover
SRTM	Shuttle Radar Topographic Mission
MCDMA	Multi Criteria Decision Making Analysis
MWSDP	Ministry of Water Sector Development Program
SNNPR	Southern Nation Nationalities and People Region
USGS	United State Geological Survey
WIDP	District Integrated Development Program
WB	World Bank

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Irrigation development is one of the key strategies to increase agricultural production to generate profit. But due to rain fed dependent agriculture in the world and rainfall variability and unreliability occurrences agricultural crops are failed and consequence, food insecurity often turns into famine (Fitsum, 2017).Thus irrigated agriculture is expected to play a major role in achieving food security and improving the quality of life, especially in the context of global population growth from 6 billion today to at least 8 billion by 2025 (Daniel, 2001).Therefore the development of irrigation and agricultural water management is key strategies to enhance productivity and reduce vulnerability to the climactic volatility in any country of the world (Mamenie, 2017). The enhanced availability of water from irrigation systems was an important building block in operationalizing the green revolution in many farming systems. But over the past six decades, the world's irrigated area has doubled, contributing to food security and a reduction in poverty (World Bank, 2019).

Nowadays, about 250 million hectares, or 17 % of the world's agricultural area, are irrigated, producing about 36 % of the world's food supplies and in terms of sales value, the contribution made by irrigated agriculture to the world's total agricultural crops is estimated at just under 50 %: this is probably due to the fact that in many irrigated areas farmers grow a greater proportion of agricultural crops (Wolff et al., 1997).

Irrigation in Africa is also an important strategies for promoting increased productivity, provided investments in irrigation are properly targeted and accompanied by complementary improvements in other agricultural inputs (Liangzhi et al., 2010). Therefore it has the potential to boost agricultural productivities by at least 50 percent, food production on the continent is almost entirely rain fed (Liangzhi et al., 2010). According to German Development Institute (2017), irrigation is also can help to improve and stabilize agricultural productivity, thereby contributing to food security and to resilience against climate change. In the early 1960s, there were 7.4 million ha of irrigated area under cultivation in Africa. Although this area has nearly doubled to 13.6 million ha after almost 50 years (FAOSTAT, 2009). Although in Sub-Sahara African countries irrigation has not yet realized its full development potential but both low agricultural productivity and the negative impacts of climate change in SSA is to expand irrigation in locations where water is available, soils are suitable, and farmers either already have the productive potential or can be supported to develop it (GDI, 2017).

The country of Ethiopia is situated in East Africa and hence agriculture is the base for people to basic fulfillment of basic needs and the country is abundant by water resource. Even if we have ample amount of water still now rain-fed agriculture is more practiced than irrigation water use (Tesfaw, 2018). Therefore irrigation development has been identified as an important tool to stimulate economic growth and rural development, and is considered as a base of food security, poverty reduction and economic development of a country (Fitsum et al., 2009). Therefore analysis of geospatial based spatio-temporal assessing of surface water irrigation potential and land suitability assessment is essential for increasing production and planning a sustainable agricultural system (Kasaye, 2019). According to MWSDP, 2002 Ethiopia, with a total area of about 1.13 million km^2, has an estimated 55 million ha of arable land or approximately half of its land mass. But the arable land potential covers both rain-fed and irrigable lands that are agro-ecologically suited to the production of a variety of agricultural crops. The total annual surface runoff (from the river basins) regardless of its distribution is estimated to be in the order of 122 billion m3.There is also an estimated 2.6 billion m3 of usable ground water Ethiopia's irrigation potential has been estimated to be around 3.7 million hectares not taking into account physical, financial & organizational constraints (Meron, 2007). Since the mid-1980s, the Ethiopian Government has responded to drought and famine through promotion and construction of irrigation schemes aimed at increasing agricultural production and poverty reduction. These are traditional, small, medium, and large-scale irrigation schemes performing at different levels (Awulachew et al., 2008). According to World Bank, 2006 report less than 5 percent (about 200,000 hectares) of the estimated potential 3.7 million hectares of irrigable land in Ethiopia is under irrigation by those level of irrigation schemes.

Gambella is one of the region in Ethiopia which is highly suitable for agriculture, In the region major rivers are the Baro, Akobo, Alwero and Gilo all of these rivers have major tributaries and are large enough for the local population to depend on, as far as present and future irrigation needs are concerned and those river basins has an abundant water and land resources (Azeb et al., 2019). Among those river basins, the Baro-Akobo river basin has the total mean annual flow from the river basins is estimated to be 23.6 BMC. Although Gambella has an abundant water and land resources, its agricultural system does not yet fully productive. This resulted from no systematic land suitability assessment, land use planning and lacking of clearly, current land use and irrigation land suitability description for potential natural resource in the area.

In the study area, Abaalemu watershed; exploitation of water resource for irrigated agriculture has remained low. The water resource of the river have been serving as sources of water for livestock, domestic water supply and sources of industrial use (coffee processing industries). There are no small or large-scale irrigation schemes in the area. This might be because of, firstly, potential irrigable area have not been identified, and secondly, the available physical land resources and socio economic factors are not known.

Therefore, to overcome these uncertainties, this study was carried out by using GIS software as a tool for assessing irrigation potential in the study area. The assessment used input data from soil, digital elevation model (DEM) data, satellite image (sentinel 2A) in order to assess and map the result in the context of surface irrigation development in the study area.

1.2. Statement of the problem

The overall impacts of climate variability on agriculture are expected to be negative, threatening global food security specially, Population in the developing world, which are already vulnerable and food insecure, are likely to be the most seriously affected (Gerald et al., 2009). Both the livelihoods of rural communities and the food security of a predominantly urban population are therefore at risk from water-related impacts linked primarily to climate variability. In Africa, most agricultural land is rain-fed and subject to erratic rainfall and recurrent droughts, leading to low agricultural sector performance. This includes low resilience of rural people to climatic effects, irregular production and low productivity, low intensification and crop diversification, and weak value chain and market development (Fethi, 2016). Even Ethiopia is also, where multitudes of its population live in rural areas; agricultural development plays a central role not only in changing rural livelihoods but also in the nation’s economic development. But due to spatial and temporal variations in rainfall constrains production of more than one crop per year (MOARD, 2010). Being dependent on rain fed agriculture, production of crop does not much with the growing population of the country. As result, the size of human being affected with famine because of the climate variability (MOARD, 2010). Hence, it is very important to invest in irrigation development so that the higher productivity irrigated agriculture becomes the main source of agricultural production (Awulachew et al., 2008).

In the study area agricultural activity mostly depends up on rain fed agriculture. But in the case of seasonal or annual climate variability, farmers of the watershed are engaged in mono-cropping cultivation system. However its agricultural system does not used fully potential and the living standard of the community is subsistence. Sustainable economic development should be supported by effective agricultural technology intervention through announcing assessed irrigation potential technology and expanding irrigation investment. This is caused from no systematic land suitability assessment, land use planning and update surface water irrigation potential in the area. Therefore surface irrigation development is very important for refining the livelihood of the people. Therefore, assessing surface irrigation in terms of suitable land and available water is a very important option for solving the problem. Thus to minimize this, remote sensing and GIS are viewed as an efficient tool for assessing of irrigation water management of the area (Nasir, 2019). Therefore potential irrigable area of the watershed have not been yet identified, no researchers have carried out on assessment of surface water irrigation potential.

Therefore, to fill the gap this research would be assess surface irrigation potential and identify suitable land for irrigation and provide maps based on physical suitability parameters by implementing Multi Criteria Analysis Methods and Geospatial technologies and other materials which are relevant to this study.

1.3. Objectives of the Study

1.3.1. General Objective

The overall objective of this study was to assess surface water irrigation potential in Abaalemu watershed of Baro-Akobo river basin in Godere district.

1.3.2. Specific objectives

The specific objectives of this study were;

- To identify suitable areas for surface water irrigation based on physical suitability factors analysis.
- To examine potential of surface water irrigation of study area.
- To provide land suitability map of the Abaalemu watershed for surface irrigation.

1.4. Research Questions

In general, the following research questions would be answered at the end of research work.

- What is the extent of suitability of Abaalemu watershed for surface irrigation?
- How to evaluate the potential of surface water irrigation in the study area?
- Wow to provide maps based on physical suitability parameters of study area?

1.5. Significance of the study

Assessing available water resources and their potential for irrigation water use is vital for sustainable agricultural development and planning (Meseret et al., 2020). Therefore analysis of scientific assessment of surface water irrigation potential and land suitability is essential for increasing production and planning of sustainable agricultural system. So that this study was significance for decision makers to provide facts or suggestion to plan and manage the surface irrigation based on the result of the study. Particularly, local community was the most beneficiary from this because of the study was assess the irrigation potential and select suitable land for irrigation of the area to develop irrigation agriculture. In addition to this the output of this research is also important for researchers, water resources managers, development agents, fund providers, socio-economic development and planners in order to have additional input for study and for making projects of study area.

1.6. Scope and limitation of the study

This study was conducted at Abaalemu watershed in Baro-Akobo river basin .Its focus to assess surface water irrigation potential and select suitable land for irrigation based on physical suitability parameters by implementing a digital elevation model (DEM) on Arc GIS considering slope and drainage map, land use land cover and soil data.

1.7 Research organization

The study was organized in five chapters, which are briefly summarized below;

Chapter 1: contains an introductory section, where as the background of the study, statement of the problem, objective of the study, significance of the study and scope of the study.

Chapter 2: describes a literature review related with other scholars.

Chapter 3: contains description of study area, materials and methods, data sources and types are included.

Chapter 4: includes result of the study and discussion, analysis of the study is presented.

Chapter 5: describes conclusion and recommendations were specified.

CHAPTER TWO

2. REVIEW OF RELATED LITERATURE

2.1. Definition of Irrigation Potential

The definition of irrigation potential is not straightforward and implies a series of assumptions about irrigation techniques, investment capacity, national and regional policies, social, health and environmental aspects, However, to assess the information on land and water resources at the river basin level, knowledge of physical irrigation potential is necessary (Kebede,2010). The area which can potentially be irrigated depends on the physical resources 'soil' and 'water', combined with the irrigation water requirements as determined by the cropping patterns and climate. Therefore, physical irrigation potential represents a combination of information on gross irrigation water requirements, area of soils suitable for irrigation and available water resources by basin (FAO, 1997).

Irrigation can be referred as the process by which water is diverted from a river or pumped from a well and used for the purpose of agricultural production .The area, which can potentially be irrigated, depends on the physical resources, soil and water, combined with the irrigation water requirements as determined by the cropping patterns and climate (FAO,1986).However, environmental and socio-economic constraints also have to be taken into consideration in order to guarantee a sustainable use of the available physical resources. This means that in most cases the possibilities for irrigation development would be less than the physical irrigation potential (FAO, 1997).

2.2. Land Evaluation and Suitability for Surface Irrigation Potential

According to International Journal of Environmental Science and Development IJESD (2013), land suitability assessment for irrigation is a very important tool not only in terms of agriculture development planning, but also to overcome the global problem of water scarcity (rainfall variability). Therefore choosing the suitable irrigation method is even more important for developing the irrigation plan on regional and national scale. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses (FAO, 1976). Therefore the evaluation of land in terms of the suitability classes was based on the method as described in FAO guideline for land evaluation. Among those methods Multi-criteria decision evaluation method was used to evaluate the physical land characteristics of the study area for surface irrigation. In addition to this there are techniques, which were used to weight and standardized the factors, which are used to evaluate the most suitable irrigation land in the study area (Hailegebriel, 2007)

Then, the factors that were considered for evaluation of the land for surface irrigation is slope, soil, drainage, and land use and land cover. After evaluating the physical land capability for surface irrigation, irrigation suitability map was developed. These Irrigation Suitability Land Classification Technical Guidelines are intended to be a practical reference for conducting economics-based irrigation suitability land classification investigations. Their use will aid in establishing a uniform approach to the variable conditions for which a land classification may be necessary and in providing an accurate appraisal of the land resource for irrigation suitability (U.SDIBR, 2005).The land suitability classification, using the guidelines of FAO (1976) is divided into Order, Class, Sub Class, and Unit. Order is the global land suitability group. Land suitability Order is divided into S (Suitable) and N (Not Suitable).Class is the land suitability group within the Order level. Based on the level of detail of the data available, land suitability classification is divided into: Highly Suitable (S1), Moderately Suitable (S2), and Marginally Suitable (S3). The “Not Suitable” order does not have further divisio

Table1: Land suitability classification

Class	Code	Description
S1	Highly suitable	land having no significant limitation for agricultural Productivity
S2	Moderately Suitable	land having some limitations that are severe for sustained productivity
S3	Marginally Suitable	land with major limitations for sustained agricultural productivity
N	Unsuitable	Land with extreme limitations for sustained agricultural productivity

2.3. Factors Affecting for Physical Land Suitability of Surface Irrigation

The basic physical factors in determining the suitability of land for surface irrigation are slope, soil, water availability and land use land cover.

2.3.1. Slope

Slope is the gradient or inclines of a surface and is often expressed as a percent. Slope is important for soil formation and management because of its influence on drainage, runoff, erosion and choice of irrigation types. The slope gradient of the land has great effect on selection of the irrigation methods. According to FAO standard guidelines for the evaluation of slope gradient, mostly slopes which are less than 2% are very suitable for surface irrigation. But slope, which are greater than 8%, are not widely recommended (FAO, 1999).

2.3.2. Water Availability

Water availability is plays a significant role to make sure the deficiency of irrigation water. If there is a shortage of water during supply in some part of the irrigation season, crop production may be suffering and the returns may decline in some part of the scheme's investment may lay idle (FAO, 2001). Therefore, water supply is a key factor to evaluate the land suitability for irrigation according to the volume of water during the period of the year when it is available (FAO, 1985).

2.3.3 Soil

The assessment of soils for irrigation involves using physical properties that are permanent in nature that cannot be changed or modified. Such physical properties include soil depth, soil texture, soil drainage (Fasina et al., 2008). Therefore the soil is a major factor in the suitability of land for sustained irrigation (FAO, 1997). Accordingly, some soils considered not suitable for surface irrigation and could be suitable for sprinkler irrigation or micro-irrigation and selected land utilization types (kebede, 2010).

2.4. Land Use Land Cover

Land use land cover are often used interchangeably. However, they are actually quite different. The Global Land Cover Network - GLCN (2006) defines the land cover as the observed (bio) physical cover, as seen from the ground or through remote sensing, including vegetation (natural or planted) and human construction (buildings, roads, etc.) which cover the earth's surface. Water, ice, bare rock or sand surfaces also count as land cover. A given land use may take place on one, or more than one, pieces of land and several land uses may occur on the same piece of land. However, the definition of land use establishes a direct link between land cover and the actions of people in their environment. Thus, a land use can be defined as a series of activities undertaken to produce one or more goods or services. Definitions of land cover or land use in this way provide a basis for identifying the possible land suitability for surface irrigation with precise and quantitative economic evaluation (Jar untorn et al., 2004).

2.5. Importance of GIS Application for Suitability Analysis

A Geographic Information System (GIS) is a computer software program used for capturing, querying, storing, analyzing, and displaying geographically referenced data. This data are data’s that describe both the locations and place of spatial features such as land parcels, roads and vegetation stands on the Earth's surface (Godchild, 2000).

It also brings GIS as a technology which is relevant to a wide variety of applications. Clearly, the increased the capacity to use large, geographically referenced data sets and make become better capabilities for rapid retrieval, visualization and manipulation inside and outside of GIS will demand new methods of exploratory for spatial data analysis that specifically fit to this data-rich environment (Wilkinson, 1996; Gahegan, 1999). Therefore applying GIS databases, more up- to-date information can be gained or information that was unavailable before can be evaluated and complex analyses can be estimated or performed. Such information can result in a good understanding of a place, or prepare for future events and conditions. The most common geo-analyses that can be done with a GIS are narrated separately in the subsequent Sub-sections.

Therefore GIS Application is a powerful technology used for systematic land suitability assessment and develop clearly current land use and irrigation land suitability description for potentially resource in the area. So for detail and accurate assessment GIS and remote sensing data inputs should be recent data layers with high spatial resolution (Tesfaye et al., 2017).

2.6. Mapping for Surface Irrigation Suitability

Mapping is the main application of GIS where things are editing tasks as well as for a map-based query and analysis (Campbell, 1984). It is the most common view for a user to work with geographic information system. It represents geographic information as a collection of layers and other elements in a map view (Kebede, 2010).Today's digital mapping and Geographic Information System (GIS) technologies can be used to create high quality informative and adaptable map products. Quality graphics and maps are a key component of many planning applications and are very important when it comes to involving members of the public in the planning process. When the public views an application, they may not fully understand what the application entails. Therefore, plans and drawings are a valuable communicative tool within the realm of the planning process. Therefore a skilled map/graphics designer can create plans and drawings that clearly reflect what is intended to be proposed. And when the message is clear, questions are more easily answered and doubts laid to rest (EcoVue, 2013). Throughout history, people have found maps to be an efficient and effective method of recording, storing and transferring information about the world around them. Maps have helped us perceive where we are in relation to the environment and to shape the communities of the future. Recently, advances in mapping technology are making a significant impact on how people pursue sustainability (Janna, 2017).

2.7. Irrigation Potential of the World

Irrigated agriculture makes an important contribution to food production and rural development for many countries of the world (FAO 2001). Even though irrigated areas contribute to an estimated 40 percent of total world food production from only 17 percent of cultivated lands. But still there are great disparities in the distribution of irrigated lands and its contribution to food security in different parts of the world (FAO, 2001). Around 65 percent of the world's irrigated lands are in Asia, while Africa and South America have less than 5 percent each respectively (World Bank, 2000).The worldwide total irrigated area was about 94 million ha in 1950 and grew to 198 million ha by 1970.In contrast, the world total irrigated area grew to only about 220 million ha by 1990, and to 263 million ha by 1996 (Sojka et al., 1998). The rate of irrigation development in the 1960s averaged almost 3 million ha a year. But assessing of additional irrigated sites in different parts of the world that increased to about 4.2 million ha a year. About 87 percent of the 27.8 million hectares developed in the period 1990-98 were in the Asia region to 36 percent in Europe and about 8 percent in South America (World Bank, 2000).

Table1: Irrigated area, by region, 1990 and 1998 (thousand hectares)

Note: The regions listed here are the former regions used in the FAO Productions book before the dissolution of the Soviet Union. This classification is used here to facilitate analytical work of the trend.

Table 2: Irrigated Area by Region

Irrigated Area By Region	Irrigated area (ha)		
	1990	1998	Increase
Africa	11,190	12,520	1,330
North and Central America	28,852	30,338	1,486
South America	9,442	10,043	601
Asia	154,580	178,752	24,172
Europe	16,572	17,050	478
Former Soviet Union	20,800	19,991	-809
Oceania	2,166	2,680	514
World	243,602	271,374	27,722

Source: World Bank report of 2000

Therefore the total area prepared for irrigation at the global scale is increasing time to time because of assessing of additional irrigation sites and cultivation of arable lands through irrigation systems (Stefan et al., 2013). But now a days the total area equipped for irrigation at the global scale is 307.6 million ha of which 255.2 million ha (83 percent) were actually irrigated around year 2005. But around 116.2 million ha (38 percent) of the total area equipped for irrigation with groundwater, 191.2 million ha (62 percent) for irrigation with surface water and 0.3 million ha (0.1 percent) for irrigation with non-conventional water sources. Out of this coverage about 69 percent of the total area equipped for irrigation is located in Asia, 17 percent in America, 8 percent in Europe, 4 percent in Africa and 2 percent in Oceania. The largest areas that cultivated by irrigation on the country level are those for China (62.4 million ha), India (61.9 million ha) and the United States of America (28.4 million ha). In general the largest extent of area actually irrigated was found for Asia as well with 186.7 million ha (73 percent) of total area actually irrigated (Stefan et al., 2013).

2.8. Irrigation Potential of Africa

Irrigation is an extremely important potential source of stability and growth for agricultural production in Africa (Shawki and Guy Le., 1990). In the early 1960s, there were 7.4 million ha of irrigated area under cultivation in Africa. Although this area has nearly doubled to 13.6 million ha after almost 50 years, in 2006 African countries irrigated just 6 percent of their cultivated land, compared with a global average of around 20 percent in Latin America and almost 40 percent for Asia. Hence the irrigation sector’s contribution to agricultural output in Africa is relatively small (FAOSTAT, 2009). Since a large proportion of irrigated land is concentrated in five countries, namely South Africa, Egypt, Madagascar, Morocco and Sudan which each have more than 1 million hectares of irrigated area. For the remaining countries, the irrigated area varies from a few thousand hectares to almost half a million hectares each for Algeria, Libya, and Tunisia (FAOSTAT, 2009). While it is true that considerable potential still exists for future expansion of irrigation, because of climate variability and rainfall scarcity in those regions where the need for irrigation development is most important (FAO, 1995). At present in Africa, out of the total cultivated area estimated at 143.3 million hectares, about 12.2million hectares benefit from irrigation. Generally Africa could irrigate 42.5 million hectares, based on available land and water resources and by far the greatest potential is found in Nigeria, which accounts for more than 2.5 million hectares. Countries such as Cameroon, Chad, Ethiopia, Mali, Niger, South Africa, Sudan, Tanzania, Togo, and Uganda each have at least 100,000 hectares of potential (Fethi ,2016).

2.9. Irrigation potential in Ethiopia

Ethiopia has a significant irrigation potential identified from both available land and water resources and the country has developed irrigation schemes in many parts of the region at different scales (Awulachew, 2010). But due to lack of standard or agreed criteria for estimating irrigation potential in Ethiopia the estimations of irrigation potential is differ one source to other. But the earlier report, for example from the World Bank (1973), showed the irrigation potential at a low of 1.0-1.5 million hectares and a high of 4.3 million hectares. There have also been different estimates of the irrigation potential in Ethiopia. In addition to this the Ministry of Agriculture (1986), the total irrigable land of the country measures 2.3 million hectares. On the other hand the International Fund for Agriculture Development (1987) gives a figure 2.8 million hectares. In addition to this, Ministry of Water Resource, (2002) set Ethiopia could potentially develop irrigation over 3.73 million ha of cultivated lands.

According to IWMI (2007), Ethiopia has a substantial amount of water resources that could play significant role in the Socio-economic development of the country. Based on the drainage condition the country's total area is divided in to 12 major basins. Those river basins has great surface irrigation potential covers in different part of the country.

Table 3: Surface Irrigation potential in the river basins of Ethiopia

Basin	Catchment Area (Km^2)	Irrigation Potentials (Ha)			
		Small Scale	Medium Scale	Large scale	Total
Abay	198,890.7	45,856	130,395	639,330	815,581
Tekeze	83,475.94	N/A	N/A	83,368	83,368
Baro-Akobo	76,203.12	N/A	N/A	1,019,523	1,019,523
Omo-Gibe	79,000	N/A	10,028	57,900	67,928
Rift Valley	52,739	N/A	4,000	45,700	49,700
Awash	110,439.3	30,556	24,500	79,065	134,121
Ganale-Dawa	172,133	1,805	28,415	1,044,500	1,074,720

Wabishebele	202,219.5	10,755	55,950	171,200	237,905
Dankal	63,852.97	2,309	45,656	110,811	158,776
Ogaden	77,121	-	-	-	-
Ayish	2000	-	-	-	-
Total	1,118,074.53				3,641,622

Source: IWMI Working paper 123: Water resources and Irrigation Development in Ethiopia

The total annual surface runoff (from the river basins) regardless of its distribution is estimated to be in the order of 122 billion m3. There is also an estimated 2.6 billion m3 of usable ground water Ethiopia's irrigation potential has been estimated to be around 3.7 million hectares (Meron, 2007). According to (World Bank, 2006) less than 5 percent (about 200,000 hectares) of the estimated potential 3.7 million hectares of irrigable land in Ethiopia is under irrigation. Generally the Ethiopian government that increase small scale irrigation by about 127,000ha and in addition to this that expand large and medium scale irrigation by about 147,000 ha. As strategy of developing irrigation the plan of the government targets to develop a total of additional 274,612 ha of land which brings the total irrigated area of about 478,000 ha by 2015 (Awulachew et al., 2005).

2.10. Irrigation Potential of Baro-Akobo River Basin

Among the twelve river basins in Ethiopia, the Baro-Akobo basin has abundant water resources, which up to now have not been developed to any significant level and it has of great unrealized potential of irrigation (Muhammed, 2016). But due to lack of information related to cultivable and irrigation suitability of the land, its agricultural system does not yet fully productive (Tesfaye, 2017). Although in the region there is small areas of irrigation coverage of the largest water project to be constructed since the 1970's is the Alwero dam, which has an irrigation potential of over 10,000 hectares (Azeb et al., 2019). But recent study conducted that the potential land for irrigation development in Gambella region where, is estimated to be 500,000 ha (Teshome et al., 2017). According to International Water Management Institute (IWMI) 2007, the Baro-Akobo river basin has an area of 76,203 Km2 and the total mean annual flow from the river basins is estimated to be 23.6 BMC. And this river basin are estimated to be 1,019,523 hectares of irrigation potential of small and large scale irrigation

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of study area

3.1.1. Location

The study area, Abaalemu watershed is one of the watersheds of the Baro-Akobo river basin in Godere district which is located between 07°12’N to 07°20’N latitude and 35°12’E to 35°25’E longitude in Majang Zone, Gambella region of Ethiopia. The largest town in the area is Metti which is 628 km to southwest of Addis Ababa. Abaalemu river is also encompasses the head of water of Gillo river (CSA, 2017).

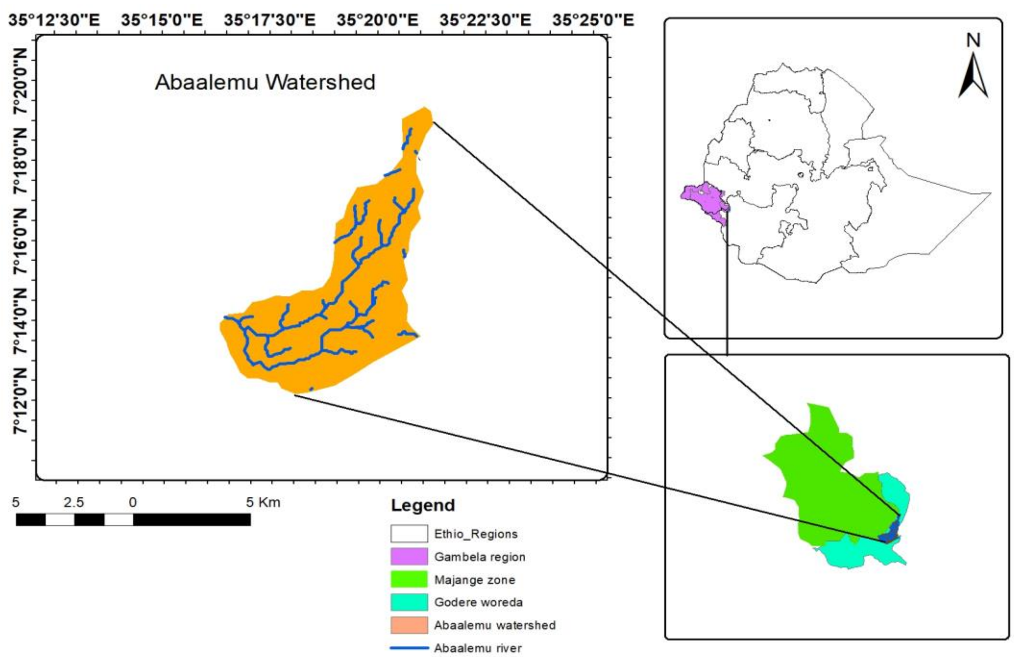

Figure 1: Geographical location map of the study area (source: Ethio GIS and CSA)

3.1.2 Climate

The climate of the watershed is a hot and humid type; average annual temperature of the area is 22° c. The mean monthly temperature varies significantly throughout the year; i.e. from 12 °c to 33° c and the maximum temperature of the area (32.7° c) is recorded in January while the absolute minimum temperature (12.9° c) is recorded in July (G RLULAS, 2004). And it receives high rainfall between mid-March to October and low rainfall from November to February average annual rainfall range of 1600-2100 mm (USAID, 2009).

3.1.3 Topography

Topography is the arrangement of the natural and artificial physical features of an area. The topography of the watershed area is characterized by a numerous tributaries, which frequently dissect the watershed. On the northern parts of the watershed the elevation is very high but in central and southern parts of the area is consists of low plateau. Generally the land elevation of the area varies from 1124 m to 1845 m above sea level.

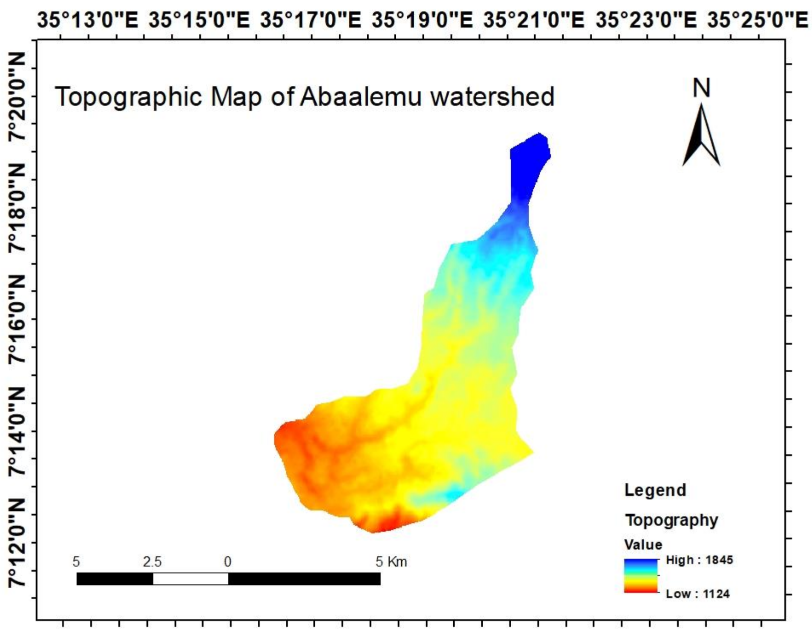

Figure 2 : Topographic map (source DEM)

3.1.4 The Socio-economic Context

Abaalemu watershed has a total population of 39,022 of which 23,204 are male and 15,818 are females (GDHOR, 2020). The majority of the population depends on agricultural economy in which the watershed is rich in cash crops and other products like coffee, cereals, fruits, spices and etc. Thus, the highest source of income for the population would be crop production and coffee plantation (CSA, 2017).The major market place is located in Metti and it is also the center of Abaalemu watershed.

3.2. Methods and materials

3.2.1. Research design

This study would be employed that the cross-sectional research methods. Because cross-sectional study design is that collect data from many different individual at a single point in time and it allows to compare many different data at the same times of the study. Therefore this study was established that cross-sectional research deals with quantifying and analyzing different spatial and numeric data's in order to get accurate results.

3.2.2. Sources and type of data collection

The most important thing for any research is collecting reliable and accurate data as it determines the quality of research. For the success of this research both primary and secondary data were used. Secondary data includes; Satellite image Sentinel 2A downloaded from USGS Earth Explorer, DEM data from ASTER web site to extract slope and drainage network analysis map, and soil data from Harmonized World Soil Data base (FAO). And primary data's include GPS data and photograph camera. On the other hand second hand information would be acquired from reliable internets, books, and journals. Generally the data sources, data collection and data analyses techniques used in this study are described below.

Table 1: Data types, sources and purpose

No	Types of data	Source of data	Purpose
1	Digital Elevation Model (DEM)	Downloaded from ASTER website	To extraction of slope map and drainage network map
2	Sentinel 2A Satellite Image	Downloaded from USGS portal http://www.earthexplorer.usgs.gov .	For LU/LC type classification and suitability analysis
3	Soil data	Harmonized World Soil Database version 1.2	For soil depth, soil texture suitability analysis
4	Administrative boundary	Ethio-GIS	For study area mapping

3.2.3. Data Collection Softwares and Instruments

The data, materials, and softwares used for the study include: GIS & RS software (ArcGIS 10.3 for spatial data analysis and map layout, ERDAS Imagine15 for land use land cover classification, Idrisi Silva would be used for weighting and rank different factor map production for pair wise comparison using Analytical Hierarchy Process, Garmin GPS 72 for taking Ground Control Point for accuracy assessment.

3.3. Data Analysis and Presentation Methods

There are different methods of GIS operation for suitability analysis like reclassify, buffering, Analytical Hierarchy Process and overlay are the major ones which would be used in this study to select suitable irrigation site.

3.3.1. Multi-Criteria Decision Making or Analysis (MCDM/A)

Multi-Criteria Analysis (MCA) concerns the making of choices using multiple, and often conflicting, criteria, in efforts to arrive at pre-considered desired outcomes. Thus MCA in particular, looks to deciding on preferences by choosing among options that refer to an explicit set of objectives assigned to the decision-making body or those identified by it (John et al., 2016). Therefore this study would be use GIS based Multi-Criteria Decision Analyses (MCDA) approach for evaluating the most environmentally suitable land for surface irrigation site in the study area. Accordingly, this research would be make MCDM for factors and lastly prioritize each of factors based on the weight that would be given by AHP calculation. The weights of relative importance of the factors guiding irrigation siting would be estimate using pair wise comparisons in AHP. In this study all criteria considered would be first converted in to raster with the same resolution. That after reclassification process would be done for all the factors, they would combine in order to find highly suitable sites in the study area.

3.3.2. Reclassify

Buffering is a zone of specified width around a point, line or polygon area one of spatial analyses tools that can help us to identify distance and proximity of the specified criteria used for suitable irrigation site selection. The criteria's would be make buffer in the study area are market and river of study area having different distance value.

3.3.3. Buffering

The physical factors such as; Slope, soil, surface water, and land use land cover and market would be reclassified with the help of reclassify of spatial analyst tools operation of the GIS. The reclassified distance would be ranked based on their suitability for irrigation site selection.

3.3.4. Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process is commonly used in multi-criteria decision-making exercises would found to be a useful method to determine the weights for each individual factor. It shall deal with inconsistent judgments and provides a measure of the inconsistency of the judgment of the factors. The GIS would be employed as a technique that provides greater flexibility and accuracy for handling digital spatial data. The combination of AHP method with GIS in our experiment proves it is a powerful combination to apply for land-use suitability analysis (Mustafa et al., 2011). AHP is a decision support tool which can be used to solve complex decision problems. And it uses a multilevel hierarchical structure of objectives, criteria, sub-criteria, and alternatives among which the best decision is to be made. Therefore AHP generates weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria in study area.

3.3.5. Weighted Overlay Analysis

Weighted overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Geographic problems often require the analysis of many different factors. For instance, choosing the site for a new housing development means assessing such things as land cost, proximity to existing services, slope, and flood frequency (Suresh and Sivasankar, 2014). Therefore Weighted overlay is a tool in spatial analyst tools that Overlays several raster datasets using a common measurement scale and weights each according to its importance. The reclassified raster would be overlay together in order to produce the most suitable area. For the weighted overlay analysis to be successful, the raster dataset must be in integer (Rakiat, 2016).In this research, map layers would be preparing, buffer, and reclassify to determine suitability level. The reclassified map would be assigned weight and overlaid together. Finally suitable irrigation site of the study areas would be select.

3.4. Description of each Parameters

3.4.1. Slope Suitability Assessment

SRTM DEM would be used to derive slope map of the study area from ASTER website. And the slope map is reclassified to achieve the required slope status. The slope map is reclassified to suitability classes of surface irrigation according to Global Agro Ecological Zone (2012). Slope class should be classified as very flat, flat, gently slope, undulating, rolling, hilling steep, and very steep with slope range given are 0-0.5, 0.5-2, 2-5, 5-8, 8-16, 16-30, 30-45, >45 respectively. Finally, code is given for each suitability level for weighted overlay to find final suitable irrigation area. The slope was considered as the main evaluation factor for surface irrigation suitability analysis. Because the slope affects water flow, fertility of soil profile, depth of irrigation, and drainage of the watershed. Slope affects the suitability of an area in terms of land preparation for irrigation and irrigation operation (U.SDIBR, 2003). It influences method of irrigation, land development, design of on farm irrigation systems, erosion hazard, drainage requirements, water use practices, crop, and other management and production costs. Thus, the study of slope is a principal factor for land suitability for surface irrigation. Therefore the slope of the Abaalemu watershed was extracted from 30 m resolution of DEM data. And the slope classes should be classified as flat, gently slope, undulating and rolling (0 – 4%, 4 – 8%, 8– 14% and 14 -35%) respectively based on (FAO, 1979).

3.4.2. Drainage Suitability Assessment

The stream flow data would be derived from SRTM DEM of 2014 which spatial resolution of 90m. The topography map is used as based map for identification of specific stream. The 90m spatial resolution DEM SRTM is resample to 30m spatial resolution in order to match which the other map layers used in this study. By using the hydrology tool, the stream network and basins would be derived. For identification of potential surface irrigation area, according to Parameter and Melcher (2010) the stream flow data are categorized or ordered according to its supply of cell count or fallow accumulation. Therefore areas of higher values of cell count are where water collects and drains; areas of very high values are likely perennial streams or rivers. In addition to this distance to water sources to be the variable most likely to influence the site location of surface water irrigation potential (Westcott and Brandon, 2016). Therefore, the map was made by creating a buffer area of specified distance to water. The vector format of buffered stream polygon converted to raster format. Then based on FAO, 1985 distance range classification; the study area classified in to four range classes; namely highly suitable, moderately suitable, less suitable and unsuitable.

3.4.3. Soil Suitability Assessment

Soil is the most important factor in determining the suitability of an area for agriculture and sustained irrigation (Dagnenet, 2013 and USDIBR, 2003). Its primary influence is on the productive capacity, but it may also influence production and development costs. Both the spatial and attribute soil data were obtained from the Harmonized World Soil Database (HWSD). The obtained soil map has 250m spatial resolution. Therefore the soil map is resampled to 30m spatial resolution to categorize the suitability class of soil depth and texture. According to its suitability for surface irrigation the previous literature of FAO (1997) is utilized. Each factor was standardized to a common measurement scale so that the results represent numeric range giving higher values to more suitable and lower values to less suitable attributes (Kassaye et al., 2019). According to U.SDIBR (2003) stated that several soil characteristics must be evaluated to determine soil suitability for irrigation. But in this study some physical soil properties (soil depth, and texture classes) was used as criteria.

3.4.4. Land Use Land Cover Suitability Assessment

To prepare land use/land cover map of the study area, Sentinel 2A of 2020 Satellite image downloaded from www.Earth explorer.USGS.gov web site. After downloaded the satellite image of the study area the image would be classified by using supervised image classification method. And reclassified into different land use land cover types on ERDAS Imagine 15 software, then different suitability classes were given to each land use land cover types. Based on these suitability classes, LULC map of the watershed was rasterized and used in the evaluation process to identify potentially suitable sites for surface irrigation development.

3.4.4.1. Accuracy Assessment

To validate and crosscheck the result of the image classification with known ground truth data, accuracy assessment would be checked for the signature values of the classified images by calculating the confusion matrix in ERDAS software. The confusion matrix is a table with the columns representing the reference (observed) classes and the row the classified (mapped) classes (Rossiter, 2001). The accuracy is essentially a measure of how many pixels in the ground truth region of interests (ROIs) are classified correctly. The image would be classified into four land classes such as forest, farm land, range land, built-up areas and 41 GCPs would be collected from each class of land use land cover. And items would be calculate include; overall accuracy, kappa coefficient and confusion matrix. The overall accuracy is calculated by summing the number of pixels classified correctly and dividing by the total number of pixels. Kappa coefficient represents strong agreement between classified land cover classes and observed land cover/use (Ephrem, 2007). It lies between 0 and 1, where 0 represents weak agreement and 1 represents strong agreement. According to Rahman et al., (2006), kappa values can be classified into three: the value greater than 0.8 represents strong agreement, between 0.4 and 0.8 represents moderate agreement and a value below 0.4 represents poor agreement.

3.4.5. Socio-economic data Analysis

3.4.5.1. Market access

Market access is directly related to distance to market .Distance to market increases the cost of inputs, increases transportation costs, and reduces the effective price farmers receive for outputs (Jeffery et al., 2012).Therefore market is used for farmers directly sell a variety of fresh fruits, vegetables, and other locally grown farm products to consumers (Phillip et al., 2021). To analyze available market for irrigational agricultural product exchange the distance from specific potential surface irrigation area to market were measured by using multiple ring buffer tool of "proximity analysis". The market suitability was categorized according to its proximity in terms of distance (Heady et.al, 2013).

Table 2: Criteria used in the evaluation of physical land suitability assessment of surface irrigation

Criteria	Condition	Factor rating	Source
Slope (%)	Highly suitable Moderately suitable Less suitable Not suitable	0-2 (flat) 2-5 (hilly) 5-8 (undulating) >8 (rolling)	Buhari,2014 USDIBR,2003 Mandal et al., 2017
Soil depth (cm)	Not suitable Less suitable Moderately suitable Highly suitable	<10 10-50 50-100 >100	FAO, 1985
Soil Texture	Highly suitable Moderately suitable Less suitable Not suitable	Loam Clay loam Sandy loam clay sandy	
Land use land cover	Moderately suitable Highly suitable Marginally suitable Not suitable Less suitable Not suitable	Range land Farmland Dispersed forest Settlement Bush Bare land	U.S Department of the Interior Bureau of Reclamation (USDIBR,2003)
Distance from water source and market center (Euclidian Distance) in km	Highly suitable Moderately suitable Less suitable Not suitable	0-5 5-10 10-20 >20	Mandal et al., 2017

Conceptual Framework

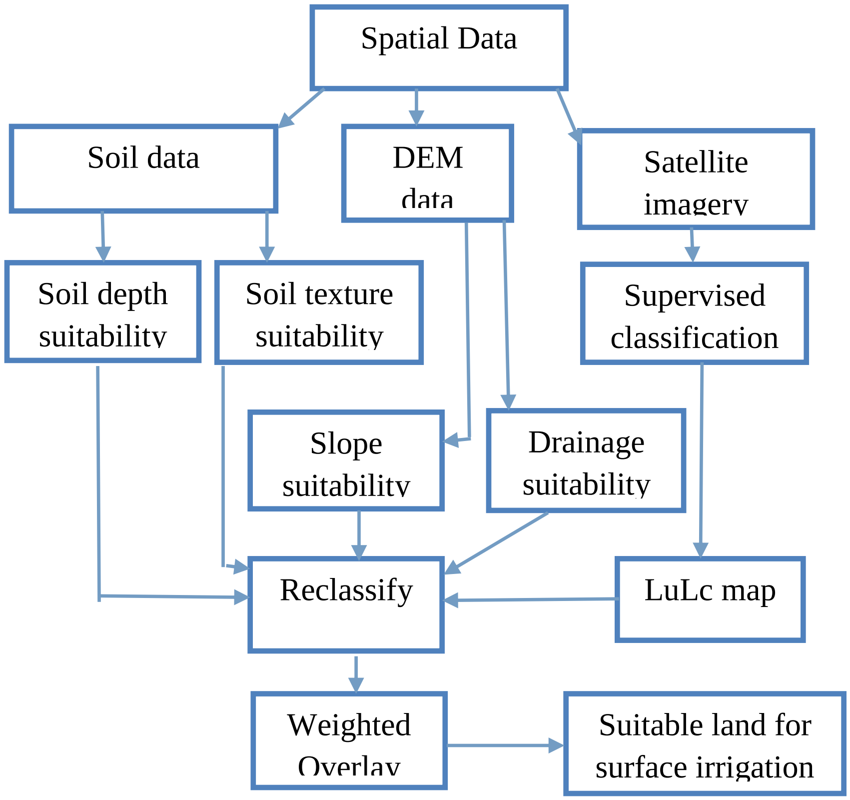

Figure 3 : Conceptual frame work of Assessment of surface water Irrigation potential in study area

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1 Analysis of Criterias for Suitable Irrigation Site

4.1.1. Slope Suitability Analysis

The slope was considered as the main evaluation factor for surface irrigation suitability analysis. Because the slope affects water flow, fertility of soil profile, depth of irrigation, and drainage of the watershed. Therefore slope affects the suitability of an area in terms of land preparation for irrigation and irrigation operation (U.SDIBR, 2003). The slope gradient of the land has great effect on selection of the irrigation methods. According to FAO standard guidelines for the evaluation of slope gradient, mostly slopes which are less than 2% are very suitable for surface irrigation. But slopes, which are greater than 8%, are not widely recommended (FAO, 1979).Therefore based on FAO, 1979 slope gradient range the study area of slope gradient classified as flat, gently slope, undulating and rolling respectively (0 – 4%, 4 – 8%, 8– 14% and 14 -35%).

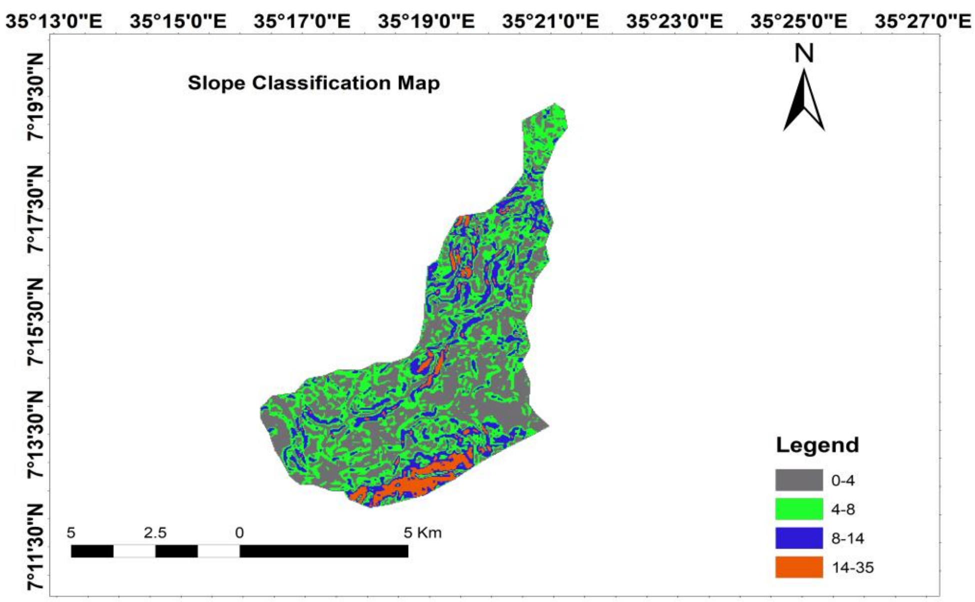

Figure 4 : Slope classification map

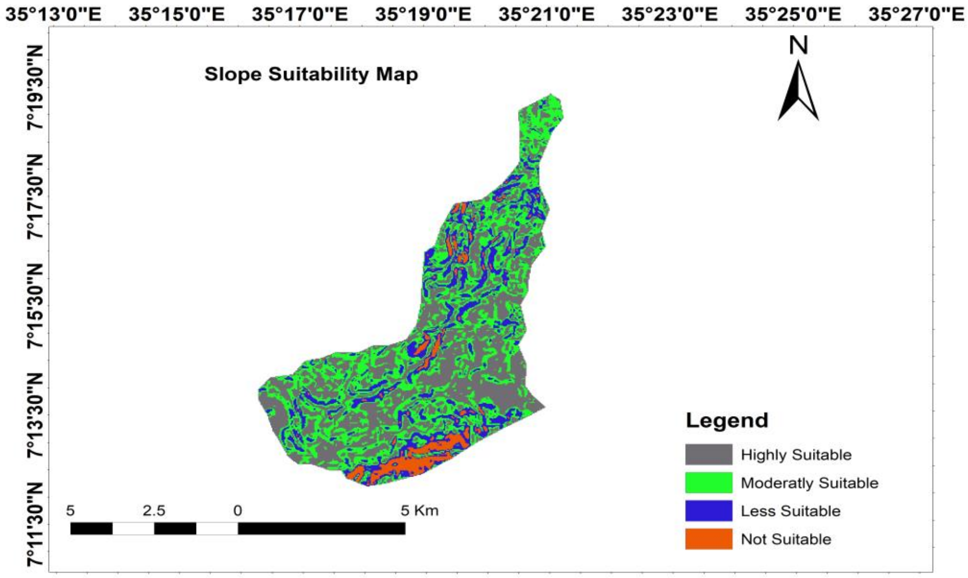

Figure 5 : Slope suitability classification

Table 3 : Slope suitability and its coverage

No-	Slope class (%)	Suitability class	Rank	Area	
				Ha	%
1	0 – 4	Highly suitable	1	1918	40.08
2	4 – 8	Moderately suitable	2	1785	37.29
3	8 – 14	Less suitable	3	833	17.40
4	14 – 35	Not suitable	4	250	5.22

The result in Table 6 indicates that, 1918 ha (40.08 %) of the study area is found within slope range of 0-4% and is highly suitable for irrigation site. This is because, this area is flat and gentle slope and hence it is not subjected to flooding. However, these areas of Abaalemu watershed are occupied by land uses like agriculture. On the other hand, 1785 ha (37.29 %) of the study area is found between 4 – 8 % slope and is moderately suitable as it is a little bit sloppy as compared to the higher suitable area. In the other class 833 ha (17.40 %) of the study area is found with slope range of 8 - 14 % and is less suitable for the irrigation site selection. The remaining which is 250 ha (5.2 %) is found within the slope >14% and is not suitable areas as it is steep slope which is highly exposed to flooding. In general the largest portion of the study area which is more than 70% is suitable for irrigation using slope as a criterion from this investigation. As it is indicated in figure 4 locational on actual ground, by using slope as a criterion, most of the southern and south eastern parts of the study area, north western parts of the area are highly suitable. Whereas the northern and north eastern parts of the area are moderately suitable, and central and southern parts of the study area are unsuitable sites as this areas are steep slope.

4.1.2. Drainage Suitability Analysis

Distance to water sources and supply of water to be the variable most likely to influence the site location of surface water irrigation (Westcott and Brandon, 2016). Therefore the irrigation channel should not be planted or constructed in the far from river or streams. This is because it needs more cost for constructing channel from the river (Mandal et al., 2017).

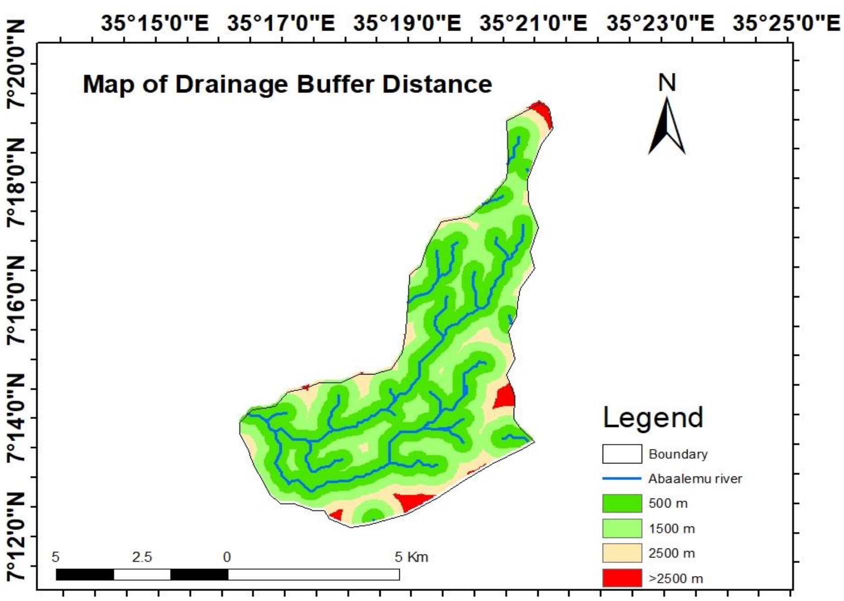

Figure 6 : Drainage buffer map

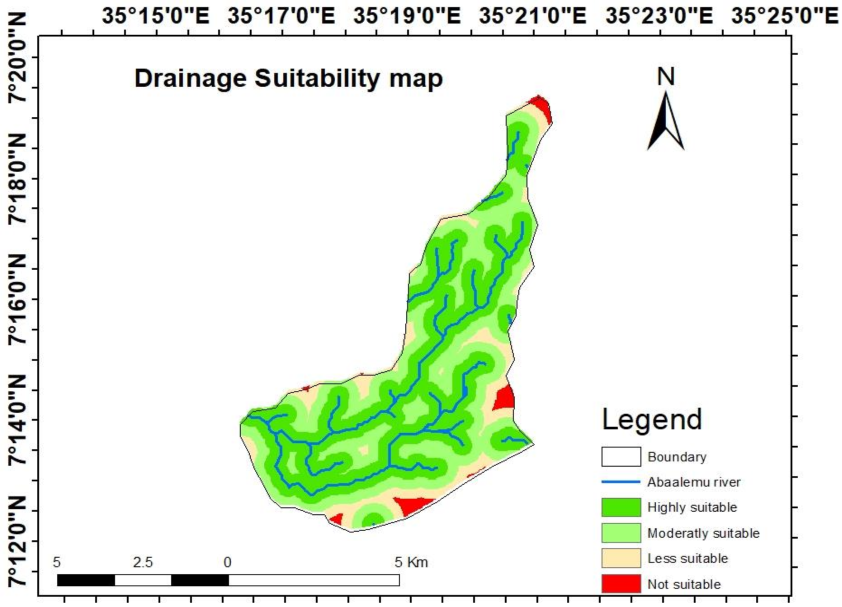

Figure 7 : Drainage suitability map

Table 4 : Drainage suitability analysis

No-	Buffer distance (m)	Suitablity class	Rank	Area	
				Ha	%
1	0-500	Highly suitable	1	2504	52.31
2	500-1500	Moderately suitable	2	1654	34.55
3	1500-2500	Less suitable	3	521	10.88
4	>2500	Not suitable	4	107	2.23

According to Mandal et al., 2017 the distance range between irrigation area and river basin is between 0-500 m is more suitable, 500-1000 m is moderately suitable, 1000-2000 m is less suitable and >2000 m is not suitable. Therefore the distance range classification of the study area were categorized in to four range classes. But because of the study area coverage and proximity to the river about 2504 ha (52.31 %) of the area is more suitable, 1654 ha (34.55 %) of the area is moderately suitable, about 521 ha (10.88 %) of the study area is less suitable. And finally, 107 ha (2.23 %) of the study area is not suitable because in case of the study area coverage and its proximity to the river.

Therefore from drainage point of view the study area which is around central and south eastern part of the area is more suitable because of its proximity to the river. And northern parts of the area is moderately suitable, north eastern parts of the area is less suitable but south eastern part of the study area is not suitable in case of study area coverage and distance to the river. Generally from drainage point of view the area is highly suitable for surface irrigation.

4.1.3. Soil Depth Suitability Analysis

Soil depth as criteria by thickness of the soil materials, which give structural support, nutrients and water for crops. A soil depth variation from place to place determines the growth of plants and also affects the growing of plant roots. (Thorne and Peterson, 1949). According to FAO,1985 the soil depth of the area >100 cm is the most suitable area for surface irrigation and the soil depth is between 50-100 cm is moderate suitable but bellow 50 cm is less suitable.

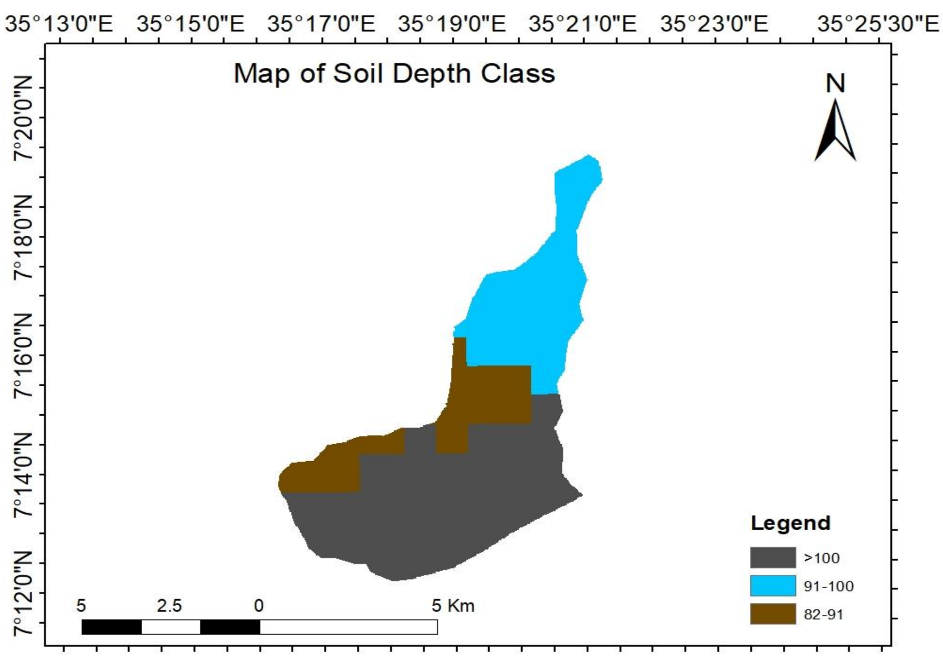

Figure 8 : Soil depth classification map

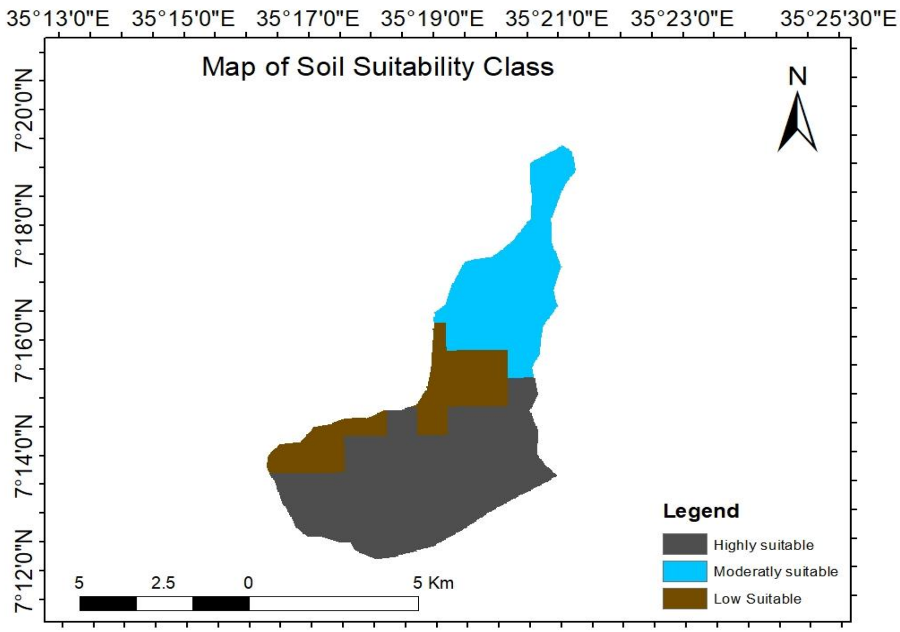

Figure 9 : Soil depth suitability map

Table 5 : Soil depth suitability class

Depth of soil (cm)	Area		Suitability level	Rank
	Ha	%		
82 – 91	2568	53.65	Less suitable	3
91 – 100	1316	27.49	Moderately suitable	2
>100	902	18.49	Highly suitable	1

Based on FAO, 1985 soil depth classification criteria's, the study area of soil depth categorized in to different classes. Therefore from the total area of study area about 902 ha (18.49 %) is highly suitable, 1316 ha (27.49 %) is moderately suitable and the largest part of study area which is about 2568 ha (53.65 %) is unsuitable. Therefore from the soil depth point of view the study area which is around southern and south eastern parts of the area are highly suitable due to its depth of soil. The soil thickness is important for the nutrient support and root growth. On other hand it receives excess water from the depth of the soil. Whereas the northern part of the study area are moderately suitable the rest central and south eastern part of the study area is not suitable from the soil depth point of view due to less categorized thickness part.

4.1.4. Soil Texture Suitability Analysis

Soil texture is one of the most important factor for selecting suitable irrigation site which is determined by the size and type of solid particles that make up the soil. Soil particles may be either mineral or organic. Based on its size soils can be divided in to gravel, sand, silt and clay. These are called the mineral fraction of soil. These gravel and sand are inactive chemically, supplying no appreciable quantities of mineral nutrients for plant use, but they do perform important function by making soils friable and providing larger pore spaces.

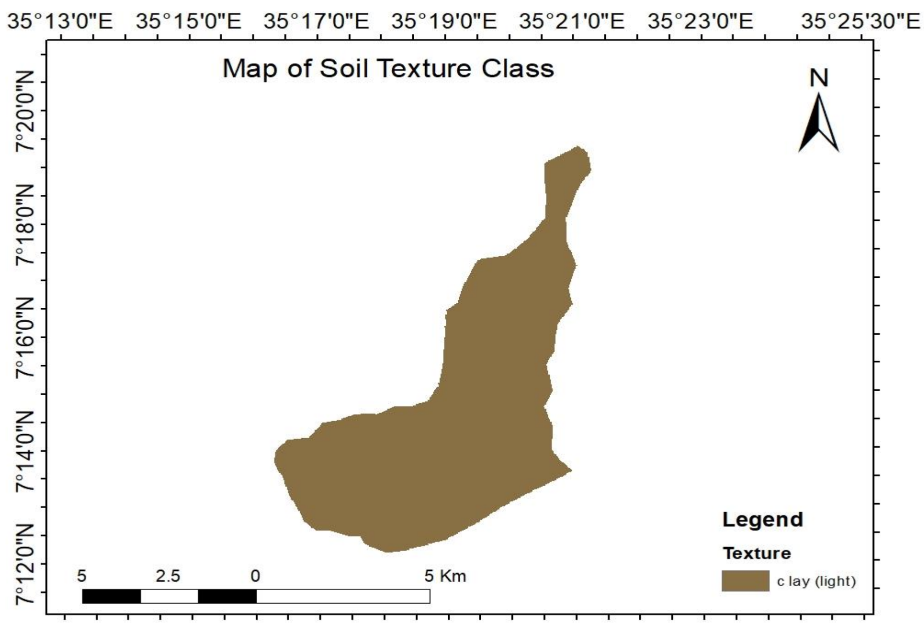

Figure 10 : Soil texture map

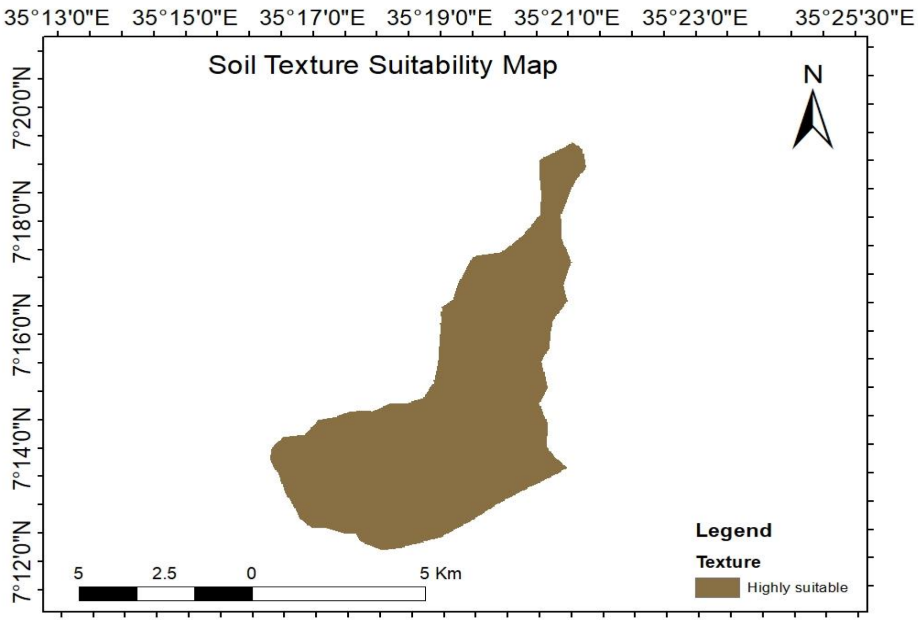

Figure 11 : Soil texture suitability map

Table 6 : Soil texture suitability evaluation

Soil texture	Area		Suitability level
	Ha	%	
Clay (light)	4786	100	Highly suitable

As U.SDIBR (2003) stated that several soil characteristics must be evaluated to determine soil suitability for irrigation. As shown in Table 9 the whole area of the basin which is 4786 ha (100 %) is highly suitable for irrigation site using soil texture as a criterion. Soil variability make difference on its nutrient and mineral composition therefore all part of the study area covered by clay light soil. Clay soil also highly nutritious and mineral composition is high therefore it is highly suitable from texture point of view.

4.1.5. Market Suitability Analysis

Market access is directly related to distance to market .Distance to market increases the cost of inputs, increases transportation costs, and reduces the effective price farmers receive for outputs (Jeffery et al., 2012). Therefore market is one of the most important factor for suitable irrigation site selection because in order to bring agricultural product to the market with minimum cost. Market which more near to irrigation site is more suitable due to its cheap transport price. According to Mandal et al., 2017 the distance range between market center and irrigation site is between 0-5 km is more suitable,5-10 km is moderately suitable, 10-20 km less suitable and >20 km is low suitable.

Therefore to analyze available market for irrigational agricultural product exchange the distance from specific potential surface irrigation area to market were measured by using multiple ring buffer tool of "proximity analysis". The market suitability was categorized according to its proximity in terms of distance. As a result, distance radius of 2000 meters is classified as highly suitable for the exchange of the irrigation agricultural products. Distance ranges from 2000-4000m, 4000-6000m and >6000m were classified as moderately, marginally and not suitable market location for irrigation agriculture product exchange respectively.

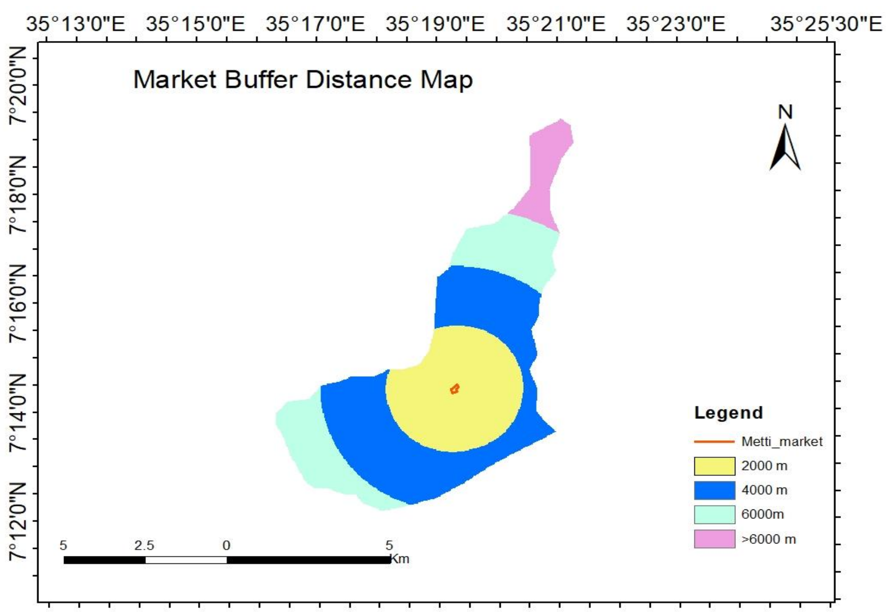

Figure 12 : Market center buffer map

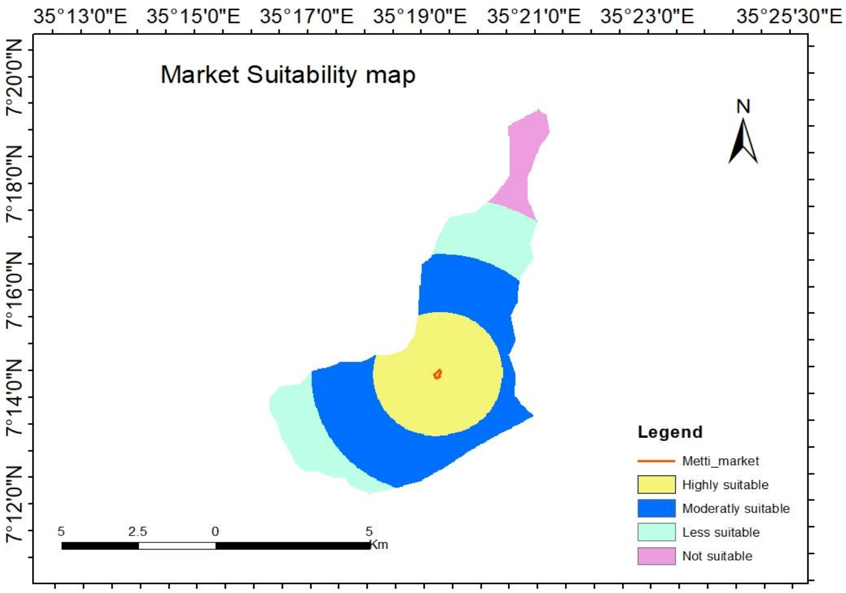

Figure 13 : Market suitability map

Table 7 : Market suitability analysis

No-	Buffer distance(m)	Suitability class	Rank	Area	
				Ha	%
1	2000 – 4000	Highly suitable	1	1328	27.74
2	4000 – 6000	Moderately suitable	2	2037	42.56
3	6000 – 8000	Less suitable	3	1093	22.83
4	>8000	Not suitable	4	330	6.89

As it is classified in Table 10 out of the total area of the watershed, 1328 ha (27.74 %) of the study area are covered with a buffer distance of less than 4000m from the market and are highly suitable for irrigation site by using market network as a criterion. This distance can minimize cost of transportation for agricultural product. On the other hand, 2037 ha (42.56 %) of the study area is classified as moderately suitable as it is relatively with better transport cost whereas 1093 ha (22.83 %) are at less suitable distance. Finally, 330 ha (6.89 %) of the study area are classified at unsuitable distance for surface irrigation site selection by using proximity distance suitability of market. This area is very far from the market which needs more transport cost than others. Using market as a criteria, most part of central part of the study area are more suitable from the market point of view these is due to nearness of the area to the market where as the south eastern part of the area are moderately suitable, south western part of the area are less suitable and north western, and northern parts of the study area are unsuitable areas from market point of view for irrigation site selection.

4.1.6. Land use land cover Analysis

Land use land cover help to identify the productivity of an area for surface irrigation. According to U.S Department of the Interior Bureau of Reclamation (U.SDIBR, 2003) the land was classified in to different land use classes and give standards for each land classes to select the most suitable surface irrigation site. Such land use classes are farm land, range land, forest, settlement, bush, and bare land. In addition to this the U.SDIBR, 2003 set standards for each land classes for selecting suitable land for irrigation. They are optimum, moderate, low, marginal, and not optimal respectively. To identify the land use land cover (LuLc) type of the study area supervised image classification method was used. So in order to find out accurate image classification we must use supervised image classification method. Satellite image of Sentinel 2A of the year 2020 was used and taking the area of interest from different Land cover type. The classification was performed using ERDAS Imagine 2015 software. Therefore based on this, the land use land cover of the study area were classified in to different land use classes such as farm land, range land, forest, and built up area.

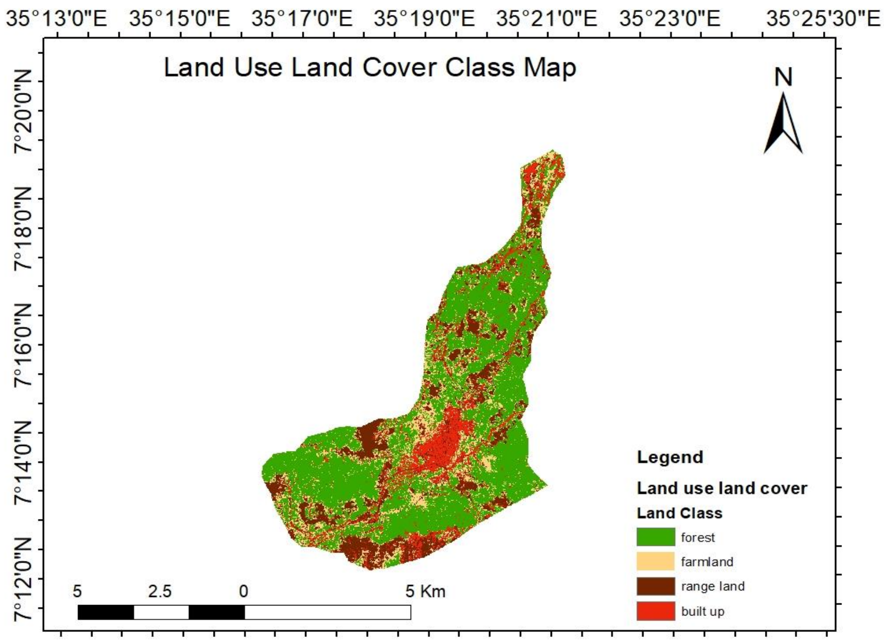

Figure 14 : Land use classification map

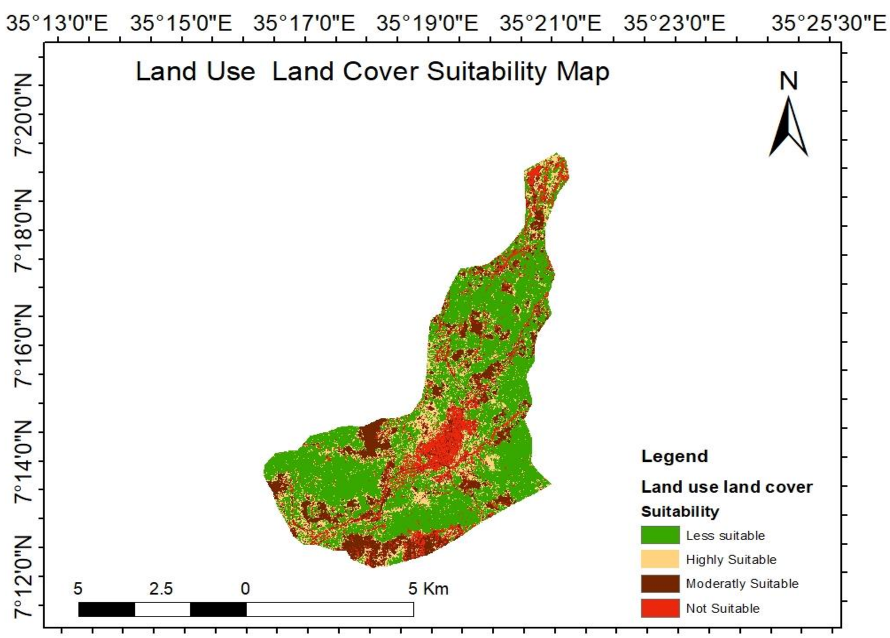

Figure 15 : Land use land cover suitability

Table 8 : Land use suitability classification

No-	Land use Land cover Class	Suitability class	Rank	Area	
				Ha	%
1	Farm land	Highly suitable	1	725	15.14
2	Range land	Moderatly suitable	2	758	15.83
3	Forest	Less suitable	3	2644	55.24
4	Built up	Not suitable	4	659	13.76

Accordingly, land use land cover of the study area was reclassified in to four classes. Namely: highly suitable, moderately suitable, less suitable and unsuitable sites for surface irrigation.

As shown in Table 11, out of the total area, 725 ha (15.14 %) of the study area is classified as farm land. But as it is mentioned in the literature, farmland is highly suitable for irrigation site as it has low impact as compared to the other land use classes. About 758 ha (15.83 %) of the study area is classified as range land, it is moderately suitable using land use land Cover classification as a criterion. On the other hand, 2644 ha (55.24 %) of the study area is classified as forest. Literatures reveal that, this class is less suitable from economic point of view and feasibility because forests have high economic value and can regulate evetn the climate. Lastly, 659 ha (13.76 %) of the study area are classified as settlement (built up area). As the image classification result indicates that most of northern tip and eastern part of the study area are more suitable for irrigation site due to its land use type which is farm land. Southern part around south western part of the area are moderately suitable from the land use land cover point of view. Most part of North West, South west and eastern part of the area are less suitable because those areas are covered by forest. The remaining central, south eastern and north central part of the area are unsuitable land use type these is due to its built up areas.

4.2. Accuracy Assessment

The accuracy assessment is essentially a measure of how many pixels in the ground truth region of interests (ROIs) are classified correctly. The image would be classified into four classes such as forest, farm land, range land, built-up areas. And items would be calculate include; overall accuracy and kappa coefficient. The overall accuracy is calculated by summing the number of pixels classified correctly and dividing by the total number of pixels, Kappa coefficient represents strong agreement between classified land cover classes and observed land cover/use (Ephrem, 2007). It lies between 0 and 1, where 0 represents weak agreement and 1 represents strong agreement. According to Rahman et al., (2006), kappa values can be classified into three: the value greater than 0.8 represents strong agreement, between 0.4 and 0.8 represents moderate agreement and a value below 0.4 represents poor agreement.

Therefore the following table are explain the accuracy assessment of each land use land cover of the study area.

Table 9 : Accuracy Assessment of each land use classes

Class	Farm land	Range land	Forest	Built up	Total
Farm land	5	0	0	2	7
Rang land	0	6	0	0	6
Forest	1	0	19	0	20
Built up	0	0	1	7	8
Total	6	6	20	9	41

Accuracy Assessment:-

User Accuracy: Farm land= 71 %

Range land=100 %

Forest = 95 %

Built up = 87 %

Producer Accuracy: Farm land = 83 %

Range land =100 %

Forest = 95 %

Built up = 77 %

Over all Accuracy: 5+6+19+7 = 37/41 =0.90 *100 = 90 %

Kappa Coefficient: $37*41—7*6+6*6+20*20+8*9/41^2—(7*6+6*6+20*20+8*9) = 85\ \%$

Therefore the accuracy assessment of the area is good because its Kappa coefficient is 0.85 (85 %) therefore it is good agreement.

4.3. Analytical Hierarchy Process (AHP)

After reclassification process was applied for all the above criteria, they were combined using weighted overlay tools in order to find and prepare thematic maps showing highly suitable sites. All the criteria considered in this study have different degree of importance and hence the importance level of each criterion in relative to the other criteria was determined. This was done for the purpose of identifying the influence of each factor relative to the other factor for irrigation site selection. Weights for each criteria considered was determined based on Multi Criteria Evaluation technique in the AHP procedure developed by Saaty, (1980). The weights for each criterion were assigned based on various reviews. Accordingly, in excel pair wise comparison matrix was developed so that weight for each criterion sums to 1.

Table 10 : Indicates pairwise matrix table for finding consistency ratio

FACTOR	SLO.	DRA.	SO.DEPTH	SO.TEX	LULC	MAR.	Weight
SLO.	1	1	3	4	4	7	0.33952
DRA.	1	1	2	3	3	6	0.280681
SO.DEPTH	0.33	0.5	1	2	2	4	0.152198
SO.TEX	0.25	0.33	0.5	1	2	3	0.105347
LULC	0.25	0.33	0.5	0.5	1	3	0.084135
MAR.	0.14	0.16	0.25	0.33	0.33	1	0.038119
TOTAL	2.97	3.32	7.25	10.83	12.33	24	

λ_{max} =6.104549

CR=CI/RI

CI= (λ**max---n)/n—1**

CI= (6.104549—6)/5 CR=0.0209/1.24

CI=0.0209 CR=0.0168

RI=1.24

4.4. Weighted Overlay Analysis

In order to make comparison of criteria one with other, being the different input factor maps have dissimilar measurement units. For instance, slope in degree, land use/land cover in class type & distance in meter so the comparison to be meaningful all values were transformed into the same unit of measurement scale to evaluation scale in which scale values of layers are weighed so they are comparable with previously reclassified datasets. The reclassified outcomes generated through the different GIS analyses were added into weighted overlay to identify coincidence of areas that can satisfy the specified suitability's ranging from restricted to less suitable, moderate suitable, and highly suitable.

As indicated on weighted overlay result in table 14 out of the total area, 254 ha (5.30 %) of the study area are found to be highly suitable for surface irrigation site because these areas fulfill the environmental and socio economic criteria. And about 3746 ha (78.26%) of the study area are moderately suitable for surface irrigation site. On the other hand, 583 ha (12.18 %) of the study area are found to be less suitable because these areas are failed to fulfill the determinant criteria that are used in the previous analysis and about 203 ha (4.24 %) of the area is built up area therefore it is not permanently suitable surface irrigation.

Table 11 : Weighted overlay result and classes

No-	Suitability class	Area	
		Ha	%
1	Restricted (not suitable)	203	4.24
2	Highly suitable	254	5.30
3	Moderately suitable	3746	78.26
4	Less suitable	583	12.18
	Total	4786	100

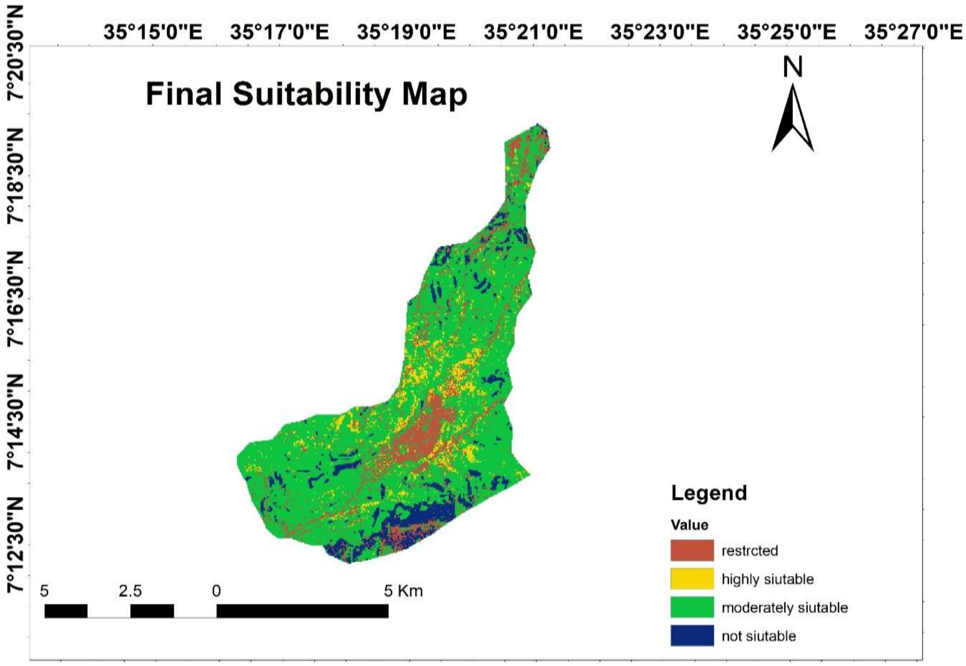

Figure 16 : Weighted overlay suitability map

The final result of irrigation suitability model analysis which involved weighting values of each data sets implies that large portion of the watershed was classified under potentially suitable for the application of surface irrigation. Where about 80% (>4000 hectare) of the Abaalemu watershed is suitable for surface irrigation and only about 4.24 % of the area coverage classified as marginaly and permanently not suitable for surface irrigation.

As the image weighted overlay classification result indicates that most of central and southeastern part of the study area were more suitable for surface irrigation site. Most parts of Southern, eastern, and south western parts of the study area are moderately suitable but northern, south eastern and some part of south western parts of the study area are less suitable.

CHAPTER FIVE

5. Conclusion and Recommendation

5.1. Conclusion

This study was conducted to assess surface irrigation potential of Abaalemu watershed, Baro-Akobo river basin in Godere district. The total area coverage of the watershed that obtained delineation is 4786 ha. It had been carried out to evaluate and estimate suitable irrigable land in the study area and develop final suitability map. The main irrigation suitability factors undertaken during the study were slope, drainage, soil depth, soil texture, land use land cover and market accessibility. Resulted from the irrigation suitability analysis; 40.08 % of slope, 52.31 % of drainage, 18.49 % of soil depth, 100 % of soil texture, 15.14 % of land use land cover and 27.74 % of market of the study area identified in the range of highly suitable to marginal suitable for surface irrigation. This indicates that most of the Abaalemu watershed was potentially suitable for irrigation development. By weighting values of each data sets using weighted overlay in Arc GIS, the irrigation suitability map was developed and potential irrigable land for surface irrigation was as 5.30 % highly suitable, 78.26 % moderately suitable,12.24 % less suitable and 4.24 % of the study area coverage classified as permanently not suitable for surface irrigation.

5.2. Recommendation

Irrigation is an important investment for improving rural income through increased agricultural production. However this can be achieved, by assessing suitable land and water resources for surface irrigation. Therefore, identified surface irrigation potential of the watershed in the study area can assist in policy and decision makers for irrigation development to alleviate the recurrent agricultural crop failure due to rainfall variability and vulnerability facing the country particularly in Abaalemu watershed in Godere district.

According to the finding of this study, potential of suitable areas of surface water irrigation were fairly selected, So that, it is better to develop and invest in those potential areas through by local farmers scaling up, NGO’s and investors.

The finding of the study can also assist policy decision during development of irrigation project in the study area.

The surface irrigation potential assessment was assessed by using the physical land resources such as; slope, soil depth and texture, drainage, land use land cover data and with the only one socio-economic factor of market accessibility factor. But the effect of the factors such as moisture of soil, fertility, soil Ph, acidity, and specific crop based analysis, economic and social terms like road (transportation) should be assessed to get sound and reliable result.

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APPENDIX

QUESTIONNAIRE

I. Appendix: Questionnaire for General Information of the Watershed.

1. Interviewer: _____________Date of interview_____________

1.1. Respondent name_______________________________

1.2. Sex: 1) Male_________ 2) Female_________

1.3. Age: 20-25_______ 26-50________ Greater than 51________

1.4. Marital status: 1) Single_______ 2) Married________ 3) Divorced______ 4) Widow _____

1.5. Education level: 1) Diploma_____ 2) Degree______ 3) Above Degree_____

1.6. Religious: 1) Orthodox_____ 2) Muslim_____ 3) Protestant_____4) Other______

1. Is there irrigation agriculture in the area?

Yes_______ No________

If say "yes"; what types of irrigation activity are there?

Traditional irrigation ________ 2) modern irrigation ________

If say "No" What are the major constraints of the water source for irrigation?
____

2. Total Irrigated Area in the watershed________________ (hectares)

3. What is the source of water for irrigation?

1) Rivers_____ 2) Springs________3) Ground Water ______4) Rain water harvesting______

4. What are the factors affecting to use irrigation?

1) Market inaccessibility_____ 2) Topography of the land______

3) Water shortage______ 4) Soil fertility _________

5. What are the methods of irrigation use in the watershed?

1) Furrow_____ 2) Flood____ 3) Drip____ 4) Sprinkler _____

6. How do you decide if land is suitable for irrigation or not?

1) Soil______ 2) slope ______ 3) Availability of water_____ 4) Land use____

II. Appendix: Ground truth points for different land use land cover types.

Point “X”	Point “Y”
759110.11	809251.17
759771.56	809105.65
758620.62	806353.98
758951.32	805864.50
757443.23	805375.02
758038.54	805203.04
756847.91	805255.95
756742.08	804819.39
757549.06	804740.02
757721.04	803390.64
757496.14	802821.78
761848.55	801035.84
756742.08	802689.49
756226.14	801882.51
755763.12	801736.99
757906.25	801604.70
756318.75	801022.61
758501.56	800771.26
758488.33	799686.46
758038.54	799871.67
757231.56	799845.21
756292.29	800109.80

753897.80	800440.53
753894.80	800003.96
756424.58	798800.11
755696.97	799355.73
753924.26	800414.07
752376.45	799937.82
753143.74	799607.09
753633.22	799421.88
754307.91	799223.44
754678.33	798548.75
754942.91	797913.75
755273.64	797755.00
754704.78	797596.25
754188.85	797384.58
753183.43	798760.42
752707.18	798958.86
752376.45	799540.94
751820.84	799660.01
753858.12	797622.71

III. Appendix: GPS points of Metti Market.

No-	x-coordinate	y-coordinate
1	757368	800760
2	756344	800830
3	756361	800853
4	756352	800882
5	756398	800917
6	756368	801004
7	756185	800845
8	756228	800724