JIMMA UNIVERSITY

SCHOOL OF POST GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDROLOGY AND HYDRAULIC ENGINEERING CHAIR

MASTER OF SCEINCE IN HYDRAULIC ENGINEERING

FLOOD HAZARD AND RISK ASSESSMENT OF UPPER AWASH BASIN USING GEOGRAPHIC INFORMATION SYSTEM: A CASE OF BARGA RIVER, OROMIYA, ETHIOPIA.

BY: TEMIRU ALEMU EDESA

A Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for Degree of Master of Science in Hydraulic Engineering

February, 2020

Jimma, Ethiopia

JIMMA UNIVERSITY

SCHOOL OF POST GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDROLOGY AND HYDRAULIC ENGINEERING CHAIR

MASTER OF SCEINCE IN HYDRAULIC ENGINEERING

FLOOD HAZARD AND RISK ASSESSMENT OF UPPER AWASH BASIN USING GEOGRAPHIC INFORMATION SYSTEM: A CASE OF BARGA RIVER, OROMIYA, ETHIOPIA.

BY: TEMIRU ALEMU EDESA

A Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for Degree of Master of Science in Hydraulic Engineering

Main Advisor Dr.-Ing. Fekadu Fufa (Associate Professor)

Co-Advisor Mr. Wakjira Takala (PhD Fellow)

February, 2020

Jimma, Ethiopia

DECLARATION

Temiru Alemu Edesa, declare this thesis is my own original work and that it has not been presented and will not be presented by me to any other University for similar or any other degree award.

Candidate	signature	date
Temiru Alemu	---------------------	--------------------

ACKNOWLEDGEMENTS

First of all, I would like to thanks to my GOD who made it possible, to begin and finished this work successfully. My gratitude and appreciation also goes to my advisor, Dr.-Ing. Fekadu Fufa (Associate professor) and co-advisor: Wakjira Takala (PhD Fellow) giving general constructive comment and suggestion to implement this study. I like also to say Ethiopian Road Authority to give this enjoyable chance with cooperative to Jimma University on the behalf of ministry of education giving great dedication, the development and completion of this study would have been impossible.

Moreover, I wish to express my deepest gratitude my partner Aberu Megersa for providing financial supporting and strength motivation to success in my study. In addition all friends and professional collogues thanks your collaboration and motivation.

Finally, my deepest gratitude and humble thanks go my immediate parents particularly my lovely mother Maste Ababa and my father Alemu Edesa, my brother Megersa and his family for their never ending support in financial, encouragement and motivation.

ABSTRACT

Flood is one of the natural hazards in worldwide both in terms of the frequency of occurrence and resulting damages. Ethiopia is a country which affected by flood in many parts of the country. The aim of this study is to identify the flood hazard and risk assessment of the Barga River using Geographical Information System (GIS) using multi criteria evaluation method. The factors that cause like: slope, elevation, soil type, geology, rainfall, drainage density, flow accumulation, topographic wetness index and land use land cover, these parameters was reclassified based on the susceptibility for the flood. Slope, elevation, drainage density, flow accumulation and topographic wetness index was derived from Digital Elevation Model (DEM) which have (12.5 x 12.5 m) spatial resolution. The other factors like: land use land cover was get from Ethiopia map service agency in raster, soil type, geology were collected from ministry of water, irrigation and electricity in the shape file form change to raster form using Arc GIS10.4.1and (1991 to 2018) daily rainfall was from meteorological service agency. The factors ranked and divided into five classes ranging from very low to very high with the integration of Geographical Information System (GIS). Weight of each deriving factors was done by analytical hierarchy process method of the nine by nine matrix was solved in IDRISI 32 software within the Consistency ratio was 0.03 the critical consistency is acceptable. Flood hazard map was done by combination of all factors within weighted overlay method and 19.06%, 20.31%, 28.18%, 22.35%, 10.09459% *of the area is under very high, high, moderate, low and very low respectively of flood hazard. Risk map was from the corporation of three parameters like population density, land use land cover and flood hazard map within equally weighted and 0.14%, 8.38%, 64.86%, 26.29%, 0.32% of the total area was under very high, high, moderate, low and very low of flood risk respectively. The flood hazard and risk map produced by GIS was validated using ground truth point location of the flooding area collected during the field surveying. The magnitude of discharge that causes flooding in watershed was calculated from daily peak discharge. The frequency was analyzed by person type III and general logistic method of the best fit selected L-moment method for 2, 5, 10, 15, 20, 25, 50, 100, and 200 of the return period.*

Keywords: Analytical Hierarchy Process, Barga River, flood hazard, flood risk, Multi Criteria Evolution,

TABLES OF CONTENTS

CONTENTS page

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AHP	Analytical Hierarchy Process
CSA	Central Statistical Agency
DD	Drainage Density
DEM	Digital Elevation Model
DSS	Decision Support System
EDRFSS	Ejere Disaster Risk Management and Food Security Sector
EHC	Ejere Health Center
EMA	Ethiopia Map Agency
EM-DAT	Emergence Events Database
FAO	Food and Agricultural Organization
FDRE	Federal Democratic Republic of Ethiopia
FMP	Flood Management Unit
GIS	Geographical Information System
GPS	Geographical Process System
IDW	Inverse Distance Weight
ITCZ	Inter Tropical Convergence Zone
MCE	Multi Criteria Evaluation
MCDE	Multi Criteria Decision Evaluation
MCDM	Multi Criteria Decision Making
MC-SDSS	Multi-Criteria-Spatial Decision Support Systems
MLM	Maximum Likelihood Method
MOM	Method of Moment
MS	Microsoft
NGO	Non Governmental Organization
MWIE	Ministry of Water Irrigation, Energy and Electricity
NMSA	National Meteorological Service Agency
PET	Potential Evapotranspiration
PWM	Probable Weight Method
RS	Remote Sensing
SDSS	Spatial Decision Support System
SNNPR	South Nation Nationality People Region
TWI	Topographic Wetness Index
USA	Unite State America
WLC	Weighted Linear Combination

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Natural disasters are common in today's world. They are outcome of sudden variation in state of natural elements due to natural forces and human existence involves exposure to many hazards. Major natural disaster like flood, earthquake, landslide, wind and drought, when those disaster are happen they result in threat of human life, loss of property; affect infrastructure, agriculture and environment.

However from the above motioned disasters flood hazard is the most common in the worlds. According to Jonkman (2005) mention that flood is one of the leading natural hazards worldwide both in terms of the frequency of occurrence and the resulting damages to human lives, the environment, and economic assets. It damage has been extremely severe in recent and it is evident that both the frequency and intensity of it is increasing.

Over the last twenty years, the overwhelming majority (90%) of disasters have been caused by floods, storms, heat waves and other weather-related events. In total, 6,457 weather-related disasters were recorded worldwide by Emergence Events Database (EM-DAT), the foremost international database of such events. Over this period, weather-related disasters claimed 606,000 lives, an average of some 30,000 per annum, with an additional 4.1 billion people injured, left homeless or in need of emergency assistance(Margareta & Debarati, 2015). During this period, average annual global losses due to floods amounted to almost US$20 billion. Between 2005 and 2014, the number of floods per year also rose to an average of 171, up from an annual average of 127 in the previous decade. For instance in the past ten years losses amounting to more than US$250 billion have had tube borne by societies all over the world to compensate for the consequences of flood(Margareta & Debarati, 2015).

Flood is the greatest hazards arising from tropical cyclones and severe storms. River floods and flash floods cause loss of life, damage to property, and promote the spread of diseases such as malaria, dengue fever, and cholera (Yonas, 2015). From 1900 to 2006, floods in

Africa killed nearly 20,000 people and affected nearly 40 million more, and caused damage estimated at about US$4 billion (Kon, 2002).

Flooding is one of the major natural hazards in Ethiopia which affects lives and livelihoods in parts of the country. Topographically, the country has highland/mountainous, plateau and lowland country. It is composed of twelve river basins, the drainage systems of which originate from the centrally situated highlands and make their way down to the peripheral or outlying lowlands especially during the rainy season (June-September), this river and the numerous tributaries forming the basin drainage systems carry the peak discharge (Woubet, *et al.*, 2014).

The flooding problem of the country is mainly linked with the topography of the highland mountains and lowland plains with natural drainage systems formed by the principal river basins. It is also likely that occasional heavy falls at places that may inundate low lying areas. Based on this scenario and the assumptions, it is estimated that 2,550,512 people would be affected by river and flash floods in 201 8 kiremt. Out of these 637,628 people across the country are likely to be displaced at some point (Joint, 2018).

Ethiopia experiences two types of floods: flash floods and river floods. Flash floods are the ones formed from excess rains falling on upstream watersheds and gush downstream with massive concentration, speed and force and often, they are sudden and appear unnoticed. Therefore, such floods often result in a considerable toll; and the damage becomes especially pronounced and devastating when they pass across or along human settlements and infrastructure concentration. The recent incident that the Dire Dawa City, experienced is typical of flash flood (Kebede, 2012). On the other hand, much of the flood disasters in Ethiopia are attributed to rivers that overflow or burst their banks and inundate downstream plain lands. This peak discharge make flood at different area of Awash Basin i.e. at upper sub basin, middle sub basin and at lower sub basin is a typical manifestation of river floods. The flood that has recently attacked Upper Awash catchment area being the flood resulting destruction and damage to life, economic, livelihoods, infrastructure, services and health system.

Barga River is one of the tributary of Awash River. It is start from Ada'a Barga district pass through Ejere district and enters to the Awash River at upper sub basin. It has the long distance to reach Awash River, through the passing way it has some tributary which enter to it. Therefore the downstream of Barga River around the entrance to Awash River it has some flood plain that affect the community live in six villages such as: Kimoyye, Inaftu, Hora, Amaro, Arabsa and Dhibu there is same flood in Ada'a Barga District in Baso village. This study was identified the area which affected by flood, when it may affected, and what types of physical element destroyed by flood using GIS.

Hence early days ground surveys method use to map and monitor floods with limitation of time and weather conditions. Nowadays use of Geographical Information System (GIS) and Remote sensing technologies has overcome the limitation of ground surveys method map of floods. Especially use of GIS and remote sensing technologies has really brought a revolution in mitigation of flood disaster with advancement of technology in today's world. Geospatial techniques have been proved to be the most effective tool for flood analysis (Emmanuel*, et al*., 2018).

1.2 Statement of the problem

According UNEP, (2002), the major environmental disasters in Africa are recurrent droughts and floods. This problem is more acute in highland areas like Ethiopia, which are under strong environmental degradation due to population pressure. Extensive flooding due to heavy rains in Ethiopia has affected thousands of people. Rainfall has caused several rivers and streams in Ethiopia to burst their banks and overflow, resulting in extensive flooding in many areas and subsequent loss of life (WFP, 2014). Flooding, as a natural phenomenon, has been occurred in many parts of Ethiopia. According to FDPPA (2007) reported that more than 500,000 people were vulnerable and about 200,000 people had been affected with 639 deaths, thousands of live stocks were killed, 228 tons of harvested crops were washed away, 147 tons of export coffee beans were lost, and 42,229 ha of crop land were inundated.

Awash River is high flooding basin from the country of rivers basin. The Awash River basin flood is at three different basins: upper sub basin, middle sub basin and lower sub basin. Upper sub basin is the basin which mostly affected sub basin from Awash River sub basin. Barga River is tributary of Awash at upper sub basin and it has flood in Ejere, and Ada'a

Barga districts. In Ejere and Ada'a Barga the Barga River affect the Villages Kimoyye, Inaftu, Hora, Amaro, Arabsa and Dhibu there is same flood in Ada'a Barga District in Baso village. Berga River has area 31729.56 ha of watershed, from this area 2980 ha this was affected by flood in 2017 (FDPPA, 2018).

Actually, this is, for the large part due to heavy rains falling for long days on the upstream highlands, high sediment concentration in the Barga River resulting in silt deposition, which aggravates the flooding problem by reducing the capacity of the channel to pass flood water downstream. The problem of flood occurs in this study area is most frequently within ten years return period. The most highly affect the area is recorded start from 1977, 1986, 1989, 1991 1996 1998,2000, 2001, 2003, 2006, 20011, 2018, and 2019 (EDRMFSS). From those recorded 1986, 1998, 2001, 2006, 2018, and 2019 the most worst period. Therefore this study recognized assessing the flood hazard and risk of Barga River.

1.3 Objective

1.3.1 General objective

The General objective of this study is the assessment flood hazard and risk of Barga River using geographic information system.

1.3.2 Specific objectives

- To prepare the hazard and flood risk map of the study area.
- To validate the flood hazard and risk map
- To determine the maximum discharge and the time of reoccurrence of the Barga River at outlet point.

1.4 Research questions

Which area of the Barga River watershed is under the flood hazard and risk during the flooding time?

What is the validity of flood hazard and risk map?

When the flood is reoccurred and how much the magnitude of the discharge?

1.5 Significance of the study

This study was find the way life and property of the local community needs to obtain future information on water resources, hydrological hazard characteristics, and its effects. The output would be used as input for decision makers (Government authorities), water resource planner, hazard management bodies, disaster management and food security sectors. The adaptation strategy would be integrated with processes to update plans, policies and programs. This study was helps to minimize loss of life and property due to flood hazards in the watershed and assure community sustainability.

1.6 Scope of the study

The scopes of the study were limited to analysis of Barga river watershed of flood hazard, risk assessment, validate the flood hazard and risk map and calculate the peak discharge return period. Flood hazard and risk assessment of river which includes of the next procedural steps: identify the deriving factor of flood hazard from the watershed map, develop the map of different deriving factor of the flood using GIS, prepare the hazard map by weighted overly analysis method and next using three factors like LULC, flood hazard and population map were weighted overly and made flood risk map of the Barga River watershed using GIS, validate the map using the field surveying and at the last analysis the peak discharge of the return period that cause the flooding in watershed.

1.7 Limitation

The challenge that face within this study: data of the study was not available, the available was not at same office and the data present in different office has missing data and timely bounded, to get the full data when collecting the general truth by GPS the weather condition was not suitable and the plain area is inundated by flood. In general there is the time and financial restriction within got the full information.

CHAPTER TWO

LITERATURE REVIEW

2.1 Flood

Flooding is a natural process and part of the hydrological cycle of rainfall surface and groundwater flow and storage. Floods occur whenever the capacity of the natural or manmade drainage system is unable to cope with the volume of water generated by rainfall. It varies considerably in size and duration with prolonged rain falling over wide areas rivers are fed by a network of ditches, streams and tributaries and flows build up to the point where the normal channel is overwhelmed and water floods onto surrounding area (Tesfay, 2018). Floods can be explained as excess flows exceeding the transporting capacity of river channel, lakes, ponds, reservoirs, drainage system, dam and any other water bodies, whereby water inundates outside water bodies areas ((Aris MM, 2003). It is a continuous natural and recurring event in floodplains of monsoon rainfall areas like Ethiopia, where over 80% of annual precipitation falls in the four wet months that means from June to September (Sanya, 2005).

The natural disaster related to the weather system variability, climate change, and environmental degradation have been frequently influencing human beings and their impacts to have greatly increased in recent decades (Vincent, 1997). Flood is one of the major natural disasters that have been affecting many countries or regions in the world year after year (Dilley, 2005). Flooding has significant impacts on human activities; it can threaten people's lives, their property and the environment. Assets at risk can include housing, transport and public service infrastructure, and commercial, industrial and agricultural enterprises. The health, social, economic and environmental impacts of flooding can be significant and have a wide community impact. The frequency, pattern and severity of flooding are expected to increase as a result of climate change. Development can also exacerbate the problems of flooding by accelerating and increasing surface water run-off, altering watercourses and removing floodplain storage (Hassan, *et al.*, 2009).

2.1.1 Flood hazard and risk

A hazard is anything that has the potential to cause harm. As such, identifying a hazard is just the first in a series of steps to assess the danger a substance or activity might pose under a particular circumstance. By analogy, any body of water puddle, bath, river, or ocean poses a hazard because someone could slip on it, fall into it, or drown in it. To make intelligent decisions, we must know more to assess whether or not a substance or behavior is dangerous in real world scenarios (https://campaignforaccuracyinpublichealthresearch.com/risk-vs-hazard/, 2019).

A risk is the possibility that a hazard will cause harm. Determining risk requires consideration of whether, how, and how much a person is exposed to a substance or activity. Using the same water analogy, there is little risk of drowning when one steps over a puddle of water. However, diving into the ocean without being able to swim poses a significant risk (https://campaignforaccuracyinpublichealthresearch.com/risk-vs-hazard/, 2019).

The terms hazard and risk are often used interchangeably. However, in terms of risk assessment, they are two very distinct terms. A hazard is any agent that can cause harm or damage to humans, property, or the environment. Risk is defined as the probability that exposure to a hazard will lead to a negative consequence, or more simply, a hazard poses no risk if there is no exposure to that hazard (https://en.wikipedia.org/, 2019).

A risk assessment takes a known hazard and evaluates its impact in real world applications (as discussed in the illustration above, taking into account such factors dose concentration, exposure pathways, and probability of exposure to determine the likelihood that any given hazard will actually pose a risk of harm. Understanding risk allows us to safely use fire, automobiles, and the stove in our kitchen, while avoiding actions that would make these hazards risk (https://campaignforaccuracyinpublichealthresearch.com/risk-vs-hazard/, 2019).

2.1.2 Factor that cause flood hazard

The flooding can be caused by, heavy rain, snow melt, land subsidence, rising of groundwater, dam failures. Moreover, since the industrial revolution, climate change has been clearly influencing many environmental and social sectors; in particular, it has been showing significant impact on water resources.

According to Tesfay (2018) the major causes of floods include intensity, duration and spatial distribution of rainfall on catchments; sedimentation on river channels and overflow of water from the river banks; steep slopes, deforestation and poor soil infiltration capacity; failure of hydrologic structures and sudden release of waters from dams; and landslides. These factors influence the magnitude, run-off or velocity of the flood and increase the of flood damage. Flood causative factors particularly in Ethiopia were identified from field surveys, and literatures are.

2.1.3 Flood disaster in Ethiopia

Risk assessment of the flood prone areas in Ethiopia is not an easy task. There is a big shortage of adequate and reliable water and soil data. Moreover, the absence of stream flow data and the secrecy about survey reports of some major rivers, classified as “International Rivers”, effectively block any thorough study of the topic (Tesfay, 2018).

Ethiopia’s topographic characteristics has made the country pretty vulnerable to floods and resulting destruction and loss to life, economic, livelihoods, infrastructure, services and health system (Yonas, 2015). Several factors could be mention as causes of flooding by different writers. Deforestation can impact hydrological processes, leading to localized declines in rainfall, and more rapid runoff of precipitation, causing flooding and soil erosion, a common phenomenon in most parts of Ethiopia (Dagnachew, *et al.*, 2003). On the other hand, the high infiltration rates under natural forests serve to reduce surface runoff and flood response. Certain types of plantation forests may also serve to increase infiltration rates through providing preferential flow pathways down both live and dead root channels. From the theoretical considerations it would be expected that interception of rainfall by forests would reduce floods by removing the proportion of the storm rainfall and by allowing the build-up of the soil moisture deficits (Calder, 1999).

According to Dagnachew, *et al*.,(2003) Land-use change due to the expansion of urban areas also affects the ground infiltration rate which in turn gives the way flooding to occur. Land-cover change has one of the causes of flooding phenomenon of Awash River basin, which resulted in millions worth of resources lost nearly every main rainy season. Low level vegetative cover could also affect infiltration and could lead to reduced groundwater levels and the base flow of streams. It is obvious that land-cover can affect both the degree of infiltration and increases runoff following rainfall events.

In August 2018, the National Meteorological service Agency (NMSA) issued a new mid-season weather analysis for the 2018 keremt season focusing on the Mid-Kiremt (June & July) Climate assessment and a Forecast for the remaining months (August and September) 2018. According to this forecast for the remaining months of the rainy season, the NMSA indicated that heavy falls and rainy showers are anticipated to occur in some parts of the country, and that dominantly near normal and above normal rainfall activity at few places.

In addition, the main rivers, namely the Upper and Lower Awash river basin, the Tekeze basin, the Lake Tana basin, Baro river basin, Omo river basin, and the Koka Dam could be at a heightened risk of flooding and requires close monitoring and prepositioning of relief items. The Ministry of Water, Irrigation and Electricity have already started discharging water from Tekeze and Koka Dams (the two dams are currently approaching its maximum water level) (Flood Alert #4, 2018).

2.2 Approaches of flood hazard assessment.

Flooding occurs when the amount of water reaching the drainage network exceeds the amount of water which can be contained by the drainage channels and overflows out onto the floodplain. Several factors influence whether or not a flood occur: the total amount of rainfall falling over the catchment, the geographical spread and concentration of rainfall over the catchment, i.e. the spatial variation, rainfall intensity and duration, the temporal variation, antecedent catchment and weather conditions, ground cover; and, The capacity of the drainage system to contain the water.

The causes of flooding are highly variable and a complex set of factors influence whether or not flooding occurs in a catchment. Localized and/or flash flooding typically occurs where there is intense rainfall over a small sub catchment which responds to rainfall in six hours or less. In urban or rural areas where drainage is poor, the risk of localized flooding is high under such circumstances. Widespread flooding and/or non-flash flooding (lasting for more than 24 hours), occurs following rainfall of high intensity or long duration over the whole or a large proportion of the catchment (Ken, 2002). Runoff is typically low in areas where the percentage of vegetation cover is high, as vegetated areas allow high infiltration elements at until the earth is saturated. Where the ground is pre-saturated, such as following a long wet period, medium rainfall events can cause flooding as runoff begins almost immediately.

Flood levels in urban areas quickly rise where the percentage of impermeable surfaces on the floodplain, such as buildings, roads and car parks, is high. On sloping concrete and bitumen surfaces, for example, runoff is immediate. The flood hazard can be assessed by two major approaches: (1) The statistical or hydrological and (2) Geomorphological (Alexander, 1993) stated that the hydrological approach comprises methods of calculating or analyzing mainly, variables like discharge, recurrence intervals, flood hydrographs, water yield from the drainage basin and hydraulic geometry. On the other hand, the geomorphological approach consists of geomorphological analysis of the land forms and the fluvial system, to be supported where ever possible by information on the past floods and detailed topographic information. In this study, hydrological data was used to do peak discharge. This yielded the return periods of each major peak discharges and the magnitude and probability of occurrence of flood peaks of specified return periods so as to help preparedness to cope with such peaks.

Flood hazard mapping was accomplished from topographical, land cover, geomorphic, meteorological and population related data. Multi-criteria decision-making technique, which provides a systematic approach for assessing and integrating the impact of various factors, involving several levels of dependent and independent, qualitative and quantitative information, was used. All data are finally integrated in a GIS environment to prepare a final Flood Hazard and flood risk map.

2.3 Flood model

The first step in management for floods is the flood hazard and risk mapping, for planning and evaluation procedures the demand for flood information and digital maps of extent and risk of flood inghas been increased. To produce these maps GIS, RS and same others flood modeling like Hec-Ras, Hec-HMS, are useful Simulation and modeling for flood estimation are rapidly developing field in hydrology. The flood simulation and model results are a good way of providing relevant information on how model is going to be having at the location where people live and how the flood will be affected.

Natural disaster such as Tsunami (USGS, 2004) and in land flood cannot be prevented but damage can be reduced by proper planning for this reason the modeling (koshimura, 2004) is essential for identifying areas likely to be affected with flood. Benefit of the integration of RS, GIS and flood modeling is to provide information for users such as land use planning, evaluation planning and environmental impact assessment.

2.3 GIS and Remote Sensing for flood hazard and risk assessment

Geographic information system (GIS) is a computer-based system that provides the capabilities for input, data management (data storage and retrieval), manipulation and analysis, and output to handle georeferenced data (Aronoff, 1995). Remote sensing is the science and art of acquiring information (spectral, spatial, and temporal) about material objects, or area, without coming in to physical contact with the objects or areas, under investigation on the map (Lillesand, *et al*., 2004). Such kind of maps will help the civil authorities for quick assessment of potential impact of a natural hazard and initiation of appropriate measures for reducing. Remote Sensing has made substantial contribution in flood monitoring and damage assessment that leads the disaster management authorities to contribute significantly.

Remote sensing technology along with GIS has become the key tool for flood monitoring in recent years. The central focus in this field revolves around delineation of flood zones and preparation of flood hazard and flood risk maps for the vulnerable areas. Flood Hazard Mapping is a vital component for appropriate land use planning in flood-prone areas. It creates easily read, rapidly accessible charts and maps, which facilitates the administrators and planners to identify areas of risk and prioritize their mitigation/response efforts.

Nowadays GIS is emerging as a powerful tool for the assessment of risk and management of Natural Hazards. Due to these techniques, natural hazard mapping can be prepared now to delineate flood prone areas he impact. Such data will help the planners and decision-makers to take positive and in time steps during pre-disaster situation. Moreover, GIS provides a broad range of tool for determining areas affected by floods or forecasting areas likely to be flooded due to high discharge of the river. Spatial data has a physical dimension and geographic location. Spatial data stored in the digital data base of the GIS, such as a digital elevation model (DEM), can be used to predict the future flood events (Kebede, 2012).

The GIS data base may also contain agriculture, socio-economic, communication, population and infrastructural data. This can be used; in conjunction with the flooding data to adopt an evacuation strategy; rehabilitation planning and damage assessment in case of a critical flood situation Flood risk assessment requires up-to-date and accurate information on the terrain topography and the use of the land.

Remotely sensed images from satellites and aircrafts are often the only source that can provide this information for large areas at acceptable costs. Digital Elevation Models can be constructed quickly or can be improved by using e.g. the raster images. Furthermore all kinds of parameters that are important for hydrological modeling is related to the land cover, e.g. permeability, interception, evapo-transpiration, surface roughness, etc. And since land cover mapping using satellite images is already common practice, the spatial distribution of these values can be easily estimated. However satellite imagery is not only useful to derive input data for the hydrologic models, but offers also good possibilities to validate the output of the models when a flooding disaster has struck.

The observed extent of the flood can then be compared with the modeled prediction. Perhaps the most promising application of RS is its use for elements at risk analysis. High resolution images offer great opportunities to identify individual structures. Recognition of the function of these structures is important for the assessment of their vulnerability and their importance and value. Especially for cities that experience fast and uncontrolled expansion into hazardous areas like floodplains, this offers an opportunity to monitor the increasing risks and impacts and to use it in their decision making process.

2.5 Previous work

Different researches have undertaken dealing with the application of Remote Sensing, GIS and MCDE in flood hazard and risk assessment. Nawaz (2006) used integrated approach of remote sensing and GIS for flood hazard assessment in the district Muzaffarabead (capital of Azad Kashmir) in Pakistan. In order to delineate flood hazard zones, in general, different thematic layers viz., floor of building, age of building, land use, vulnerability map and building material map were developed from topographic sheet, field survey and Muzaffarabead guide map. Then classified hazard zones were developed for the district

Muzaffarabead. The study has demonstrated the capabilities of using remote sensing and GIS for detailed mapping of flood hazard zone.

In order to produce flood hazard map of the Kosi River Basin, North Bahir, India, a GIS model was used to integrate various factors such as topographical, land cover, elevation, vegetation, distance to active channel, geomorphic and population related data (Bapalu, 2006). Each factor was divided into sub factors. The study has also focused on the identification of factors controlling flood hazard in the study area. It accomplishes this goal by combining Spatial AHP technique with GIS-based overlay analysis.

The research done using GIS is flood hazard and risk assessment in fogera woreda using GIS and Remote Sensing (Woubet, *et al*., 2014). Apply modern techniques like GIS and Remote Sensing for the assessment of flood hazard and flood risk in Fogera Woreda. The flood causative factors were developed in the GIS and Remote Sensing environment and weighted and overplayed in the principle of pair wise comparison and MCE technique in order to arrive at flood hazard and flood risk mapping.

Assessment of flood risk in dire dawa town, eastern Ethiopia, using GIS (Daniel, 2006). This paper studied flood risk analysis of Dire Dawa town and flash flood hazard mapping of Dechatu catchment. To do this an original GIS-based approach was used to build geo-database for the selected flood hazard layers and elements at risk (land use and population density). Each factor was standardized and then a pair wise comparison method was used to determine the factor weights. Then weighted overlay analysis in multi criteria evaluation (MCE) was used to carry out flood hazard and risk analysis.

Application of GIS and Remote Sensing for flood hazard and risk analysis: the case of Boyo catchment (Destaye 2009). An integrated Remote Sensing and GIS approach was found to be very helpful to delineate flood hazard and risk zones in the study area. Factors that were found to be significant in triggering flood hazard in the study area in decreasing order of importance were: drainage, elevation, geomorphology, land use land cover, rainfall and slop. These factors were weighted in hierarchical order using the MCE approach to produce flood hazard map of the catchment

CHAPTER THREE

MATERIAL AND METHODS

3.1 Description of the study area

The area is bounded between latitude 8^0 50' 46" to 9^0 2'00" North and longitude 38^0 19' 56" to 38^0 30' 59" East. This study was conducted on Barga River Oromiya Regional State in the central highlands of Ethiopia. It is found at 58 km west of the Finfine on the main road to Ambo. The area receives an average annual rainfall of around 1100 mm, more than 85% of which falls in the main rainy season (June to September). The average annual temperature ranges from 6 to 21°C (https://en.m.wikipedia.org/1/2019, n.d.).

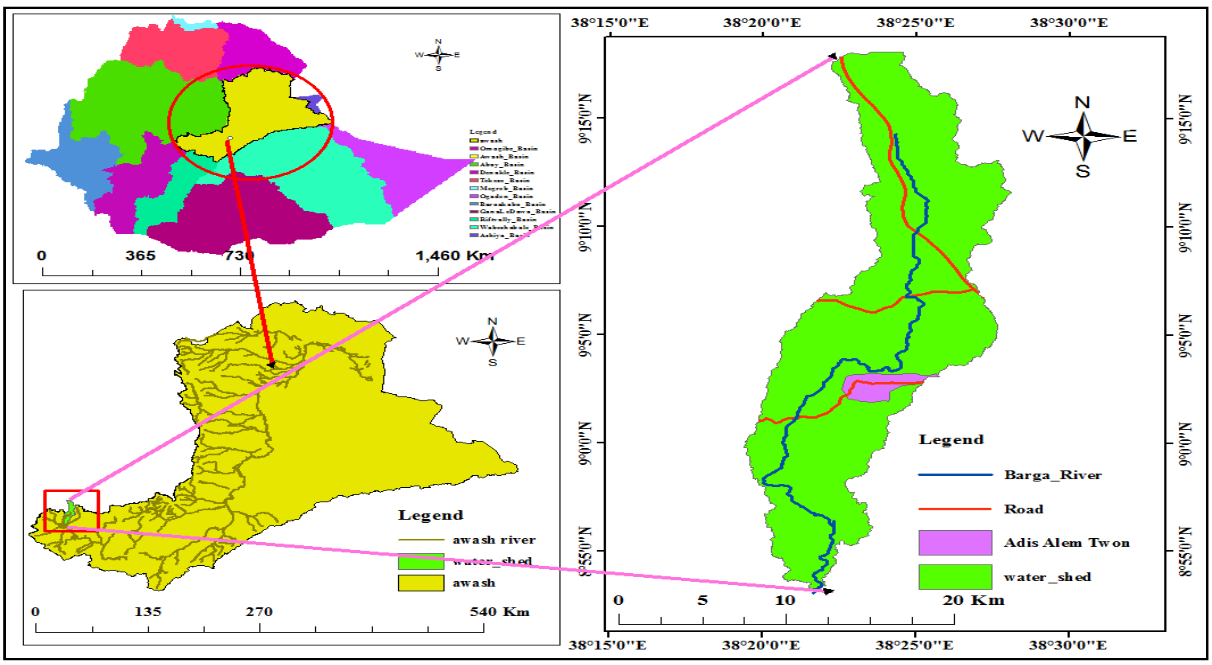


Figure: 3. 1 Study area

3.1.1 Topography of the watershed

The study area has some flat area, which at the different area mostly around confluence Awash River and at the downstream flow the velocity of water is decrease then sediment which transported by river was settled and made delta around there, delta at downstream made flat surface land. The study area has a diverse altitudinal difference which ranges from 2050 to 2922 m.a.s.l.

3.1.2 Climate

The climate in the study area falls, as a whole, into the Inter-Tropical Convergence Zone (ITCZ). The climatic zone of the Watershed based on the agro climatic classification method (altitude and rainfall) is classified as Moist Dega (2300-3200 m.a.s.l) and Weyna-Dega (1500-2300 m) (Woubet, *et al.*, 2014). Based on the topographic condition, the climatic condition of the watershed varies from one area to another in terms of both temperature and rainfall. The long year rainfall and temperature data were collected from the following five stations: Addis Alem, Kimoye, Enselale, Aruse and Olonkomi. But Olonkomi station has no temperature.

3.1.2.1Rain fall

Rainfall data from five meteorological stations have been collected and analyzed. The rainfall pattern has a bimodal nature in which the months from March to May and June to September are marked by relatively higher rainfall records. The long rainy season in the area is between, June to September, during which crop cultivation takes place in the catchment. Total annual rainfall ranges from about 750 mm to 1600 mm/year and the spatial distribution of rainfall shown in (Figure. 3.2). There is a considerable variation of rainfall year by year. Approximately about 85% of the annual rainfall occurs during the rainy season which extends from June to September. This constitutes one of the restrictions to agricultural development in the study area.

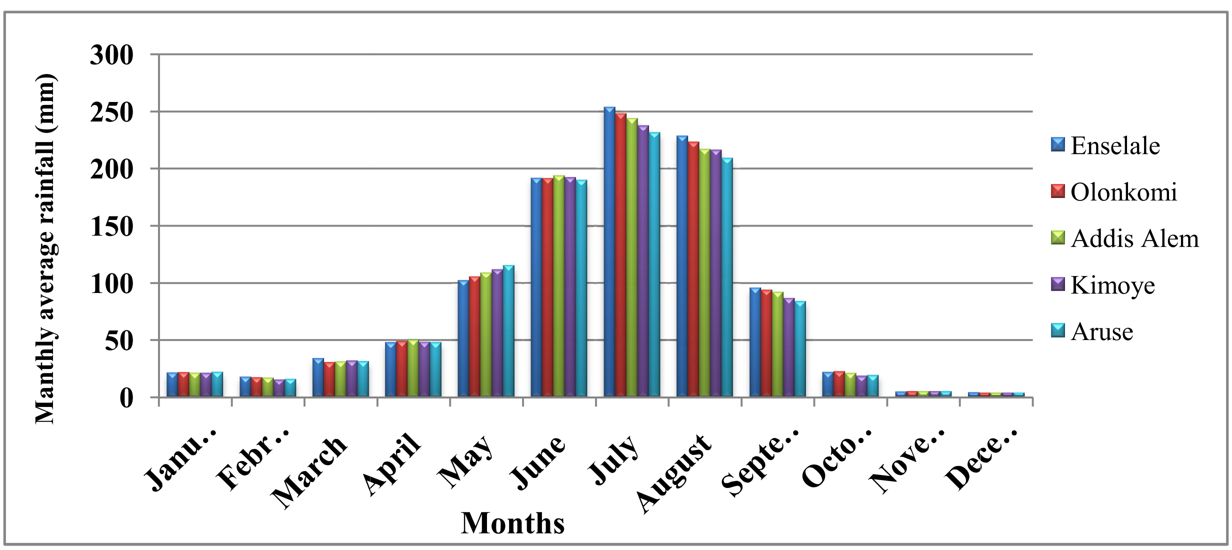


Figure: 3. 2 (1991 – 2018year) Average monthly representation precipitation of five stations

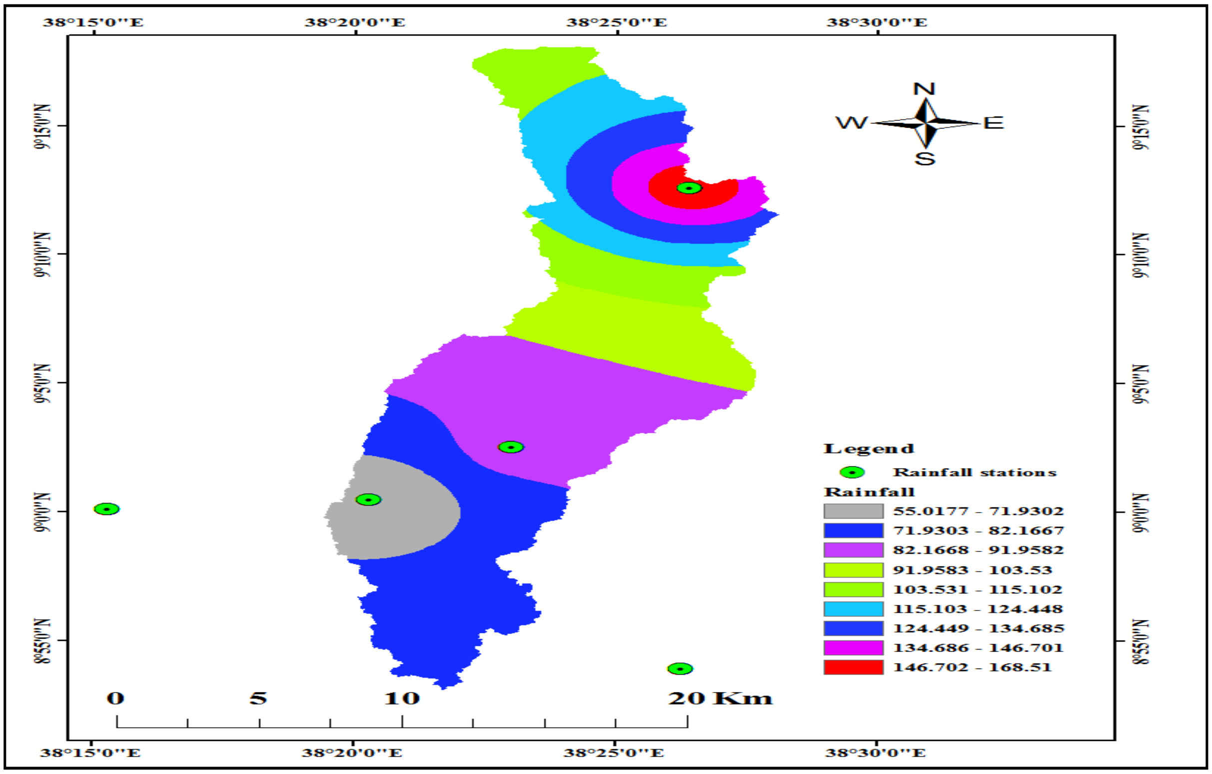


Figure: 3. 3 Rainfall stations map

3.1.2.2 Rainfall Trend analysis

Rainfall data was get from Ethiopia National Meteorological Service Agency (NMSA) is the daily rainfall data that start from (1991-2018 years) but it has same missing day. To fill of the missing data was using the XLSTAT 2015 software and the maximum monthly data arranged for GIS using MS Excel as point data. The long year monthly maximum rainfall trend (Figure 3.4) shows that there is a slight decrease in monthly maximum rainfall (1991-2018 years). There were high monthly maximum rainfall peaks in the middle of 1998 and around 2010 even though the several flood in Barga watershed occurs in many years. Here one can judge that the recent flood in watershed in Barga watershed in particular is not caused mainly from rainfall. The minimum rainfall of the study area is at 2002 and 2011 that show there is the drought in these years.

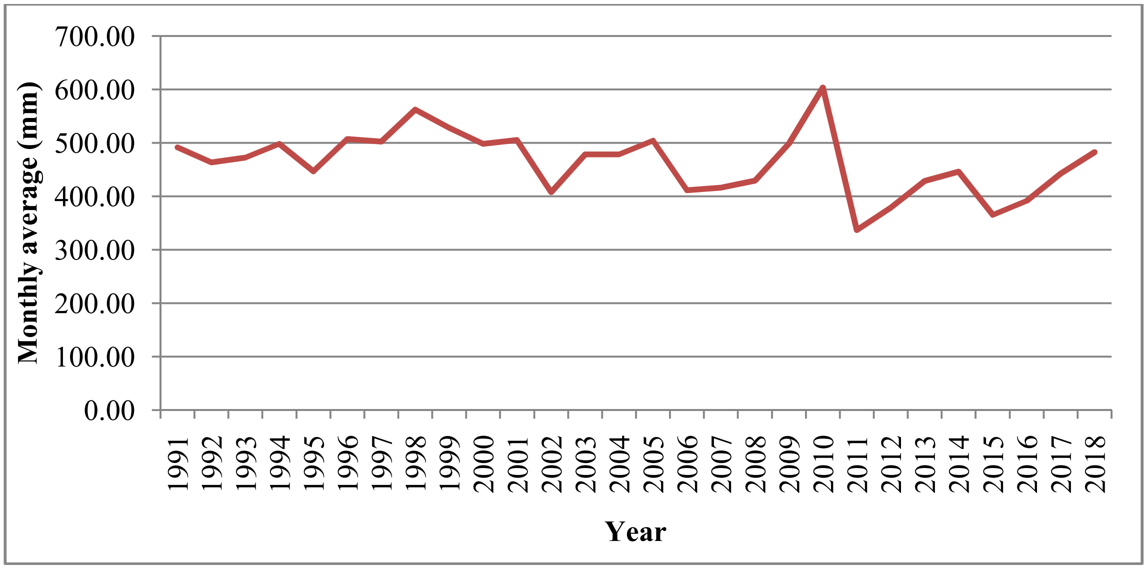


Figure: 3. 4 Trend in Average Monthly Max Rainfall of five Meteorological stations

3.1.2.3Temperature

The monthly maximum and minimum temperature for the years from 1991 to 2018 was available at four meteorological stations. The highest mean maximum monthly temperature was generally observed during the dry season. The fluctuation of monthly mean temperatures is relatively small. The daily mean temperature ranges between 15.1^{0}C and 18.5^{0}C in the area. However, the daily fluctuation of temperature is remarkably great. The minimum and maximum temperatures in a day record show 4^{0}C and 32.5^{0}C in the area. The monthly average relative humidity is 54.3%.The monthly average wind velocity is 1.7 m/s in the plain area. The average sunshine duration is 7.8 hr/day

3.1.3 Drainage of the watershed

The river originate on the high elevated at the north east in Ada'a Barga district to the south west, pas through the Ejere district and come to the Awash River at downstream the gradient decreases and it form meanders. During and after the rainy season, as the Barga River approaches the Awash River, water overflows its banks and floods the surrounding area. There is same swamp has been formed around the mouths of this river during the rainy season. The stream discharge trend at the gauge station kimoye is shown as (Figure: 3.5). This discharge is available for thirty eight years that means start from 1975 to 2012 year.

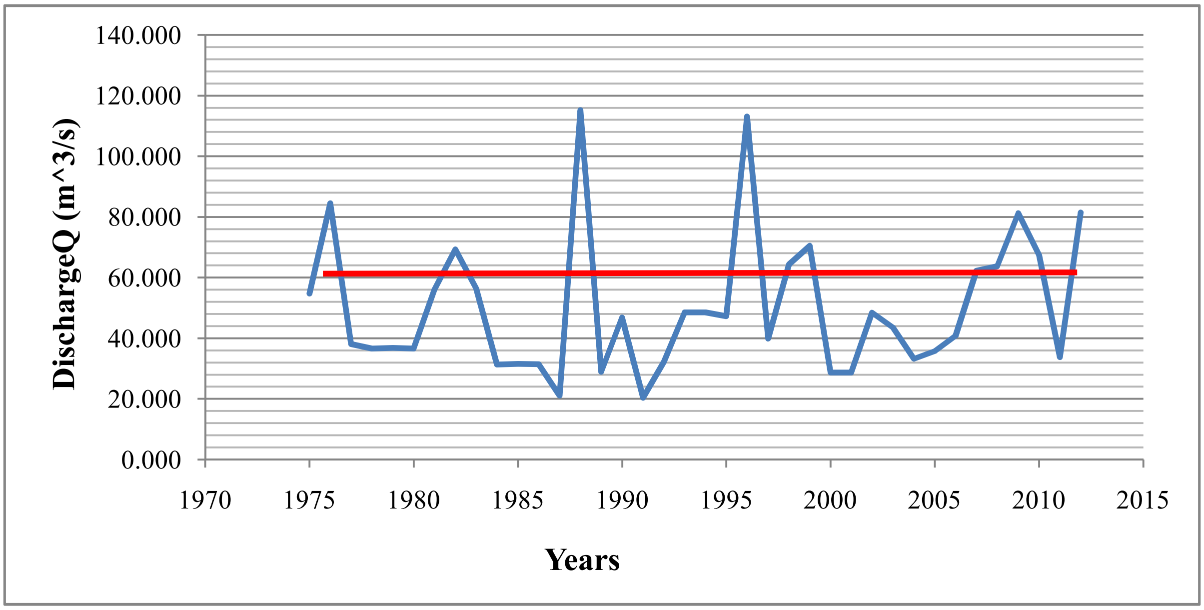


Figure: 3. 5 Stream discharge gauge at Kimoye

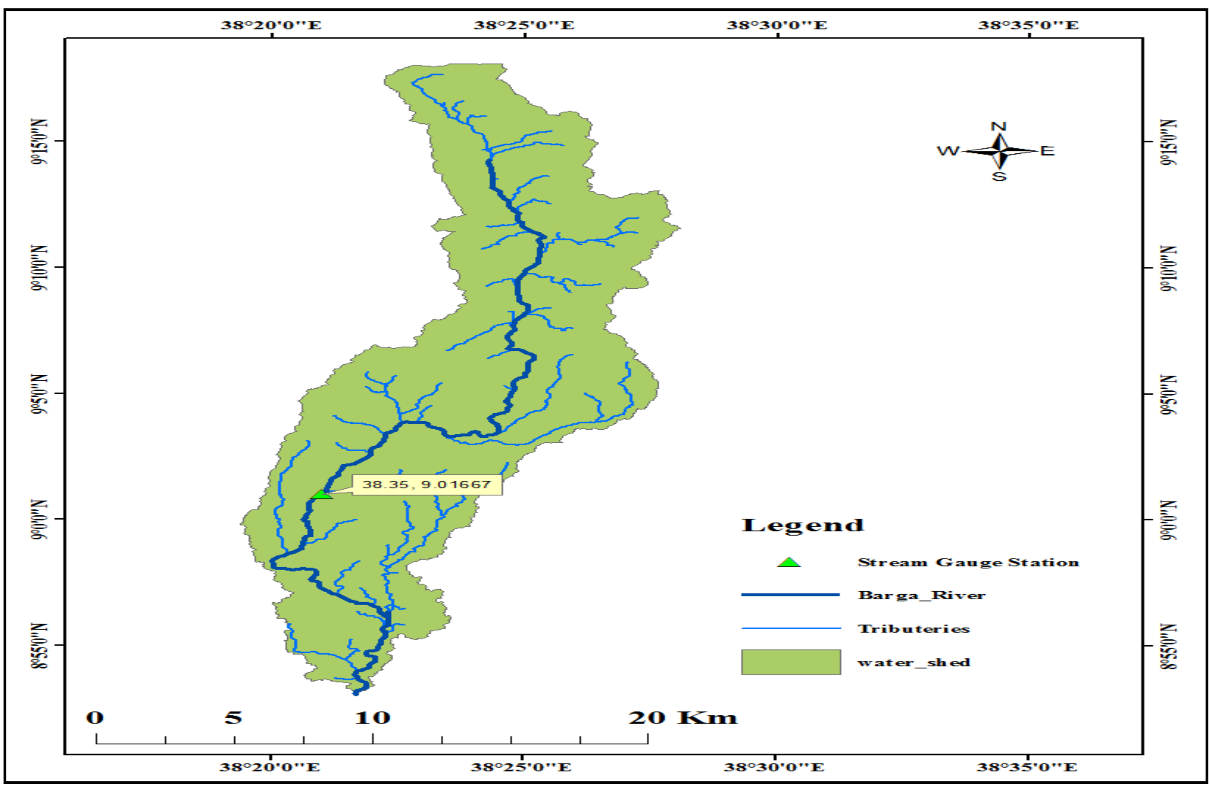


Figure: 3. 6 Drainage of the watershed map

3.1.3.1 Stream gauge level trend analysis

Stream gauge of the Barga River is get from the Ministry of Water, Irrigation and Electricity (MWIE) is the daily data start from (1975 to 2012 years) but it has same missing. The filling of the missing stream gauge daily was done by average method. The daily maximum of the stream gauge is selected for the peak discharge and time of reoccurrence. Before analysis the frequency data the hydrograph of the stream gauge was be analyzed.

As discussed in the previous section over flow of Barga River causes flooding in watershed. Large areas the lie below the point where there is a sharp decline elevation (2400 m) is prone to flooding in the main rain season. The hydrograph of the river on (Figure 3.7) shows that the wet seasons contribute the dominant share of gauge level of this river. During the rest eight months the level is extremely small. This indicates a lower contribution of the base flow in to the river. On the other hand this shows runoff during rainfall is dominantly overland flow sub-surface flow processes generally being minor. Such highly peak hydrograph in the wet season or very small base flow is closely linked to very low infiltration rate and quick overland flow. In other words it shows the absence of water abstraction.

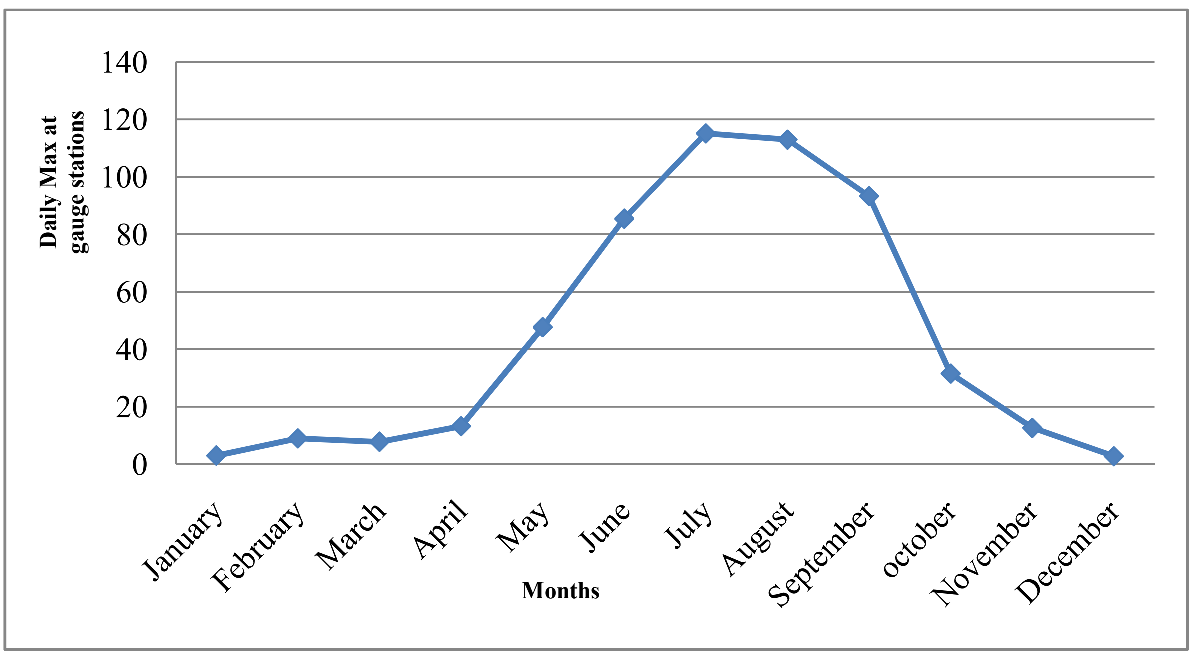


Figure: 3. 7 Hydrograph of Barga river watershed (1975 to 2012 years)

3.1.4 Present land use land cover

The study area is densely settled and is intensively used. The farming is agro-pastoral, with livestock providing the power required for land preparation. Teff is the major crop in the area and is cultivated on both the upland and in the seasonally inundated area. Based on the field survey and aerial photo interpretation, eleven land use classes are identified based on broad classes of use, the type of cropping and the spatial intensity of cultivation (the proportion of the unit occupied by cultivated fields in any one year). The Barga watershed has agricultural land for crop cultivation accounts for 60% of the study area, the grazing land 23.28%, shrub land 9.58% of the study area and the remaining 7.54% of the area is accounted for by wood land, forests land, wood land, settlement land, bare soil and wetland. As a result of increasing pressure of population on the land resources of the Study Area, there has been considerable encroachment of grazing areas by cultivation shown as (Figure 3.8).

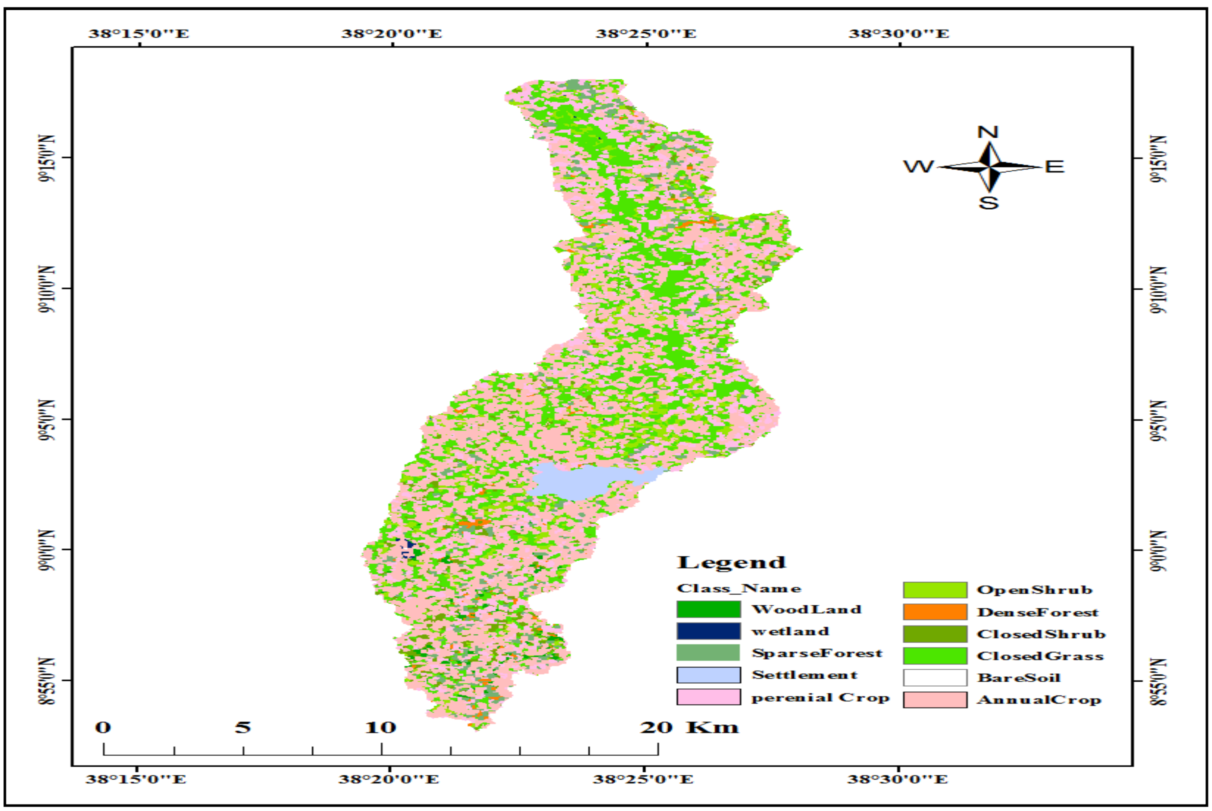


Figure: 3. 8 Land use Land cover Map of (2013 year)

Table: 3. 1 Land use land cover (LULC) area of the watershed

Land Use /Land cover Type	Area	
	Ha	%
perennial Crop	5121.484	16.140
Annual Crop	13585.078	42.814
Wood Land	219.656	0.692
Bare Soil	2.359	0.007
Closed Grass	7387.047	23.280
Dense Forest	258.609	0.815
Sparse Forest	1354.719	4.269
Wetland	26.625	0.084
Settlement	735.828	2.319
Open Shrub	2084.250	6.569
Closed Shrub	955.156	3.010

3.1.5 Rural infrastructure

The rural infrastructure in the study area is very poor. There are only footpaths connecting villages with the route, and two asphalt roads Finfine to Ambo, and Holata to Muger. The local people, especially those living on the right and left bank of the Barga River, were having difficulty access to the rural centers Inaftu village, Hora, Dhibu and Amareso village because of floods and are often isolated. Activities of agricultural extension services are also facing a difficulty owing to lack of all-weather roads within the area.

3.1.6 Soil type

Soils in the study area are classified by the Ethiopia soil classification system (FAO, 2001) and mapped by mapping units defined based on combination of soil and land form characteristics. The soils do not show extensive variation, and are limited to the five main classes of Vertisols, Cambisols, Xerosols, Nitisols, and Solonchacks. The major soil types in Watershed exhibit a general relationship with altitude and slopes. Texturally the soils are characterized as clay, sandy, Silt clay, sandy clay and sandy loam soil respectively. The soil type of the study area can be classified as the most part of the floodplain is Pellic vertisoils and along the Awash River flow the lift and right bank of the river is chromic cambisoils (MWIE, 2018).

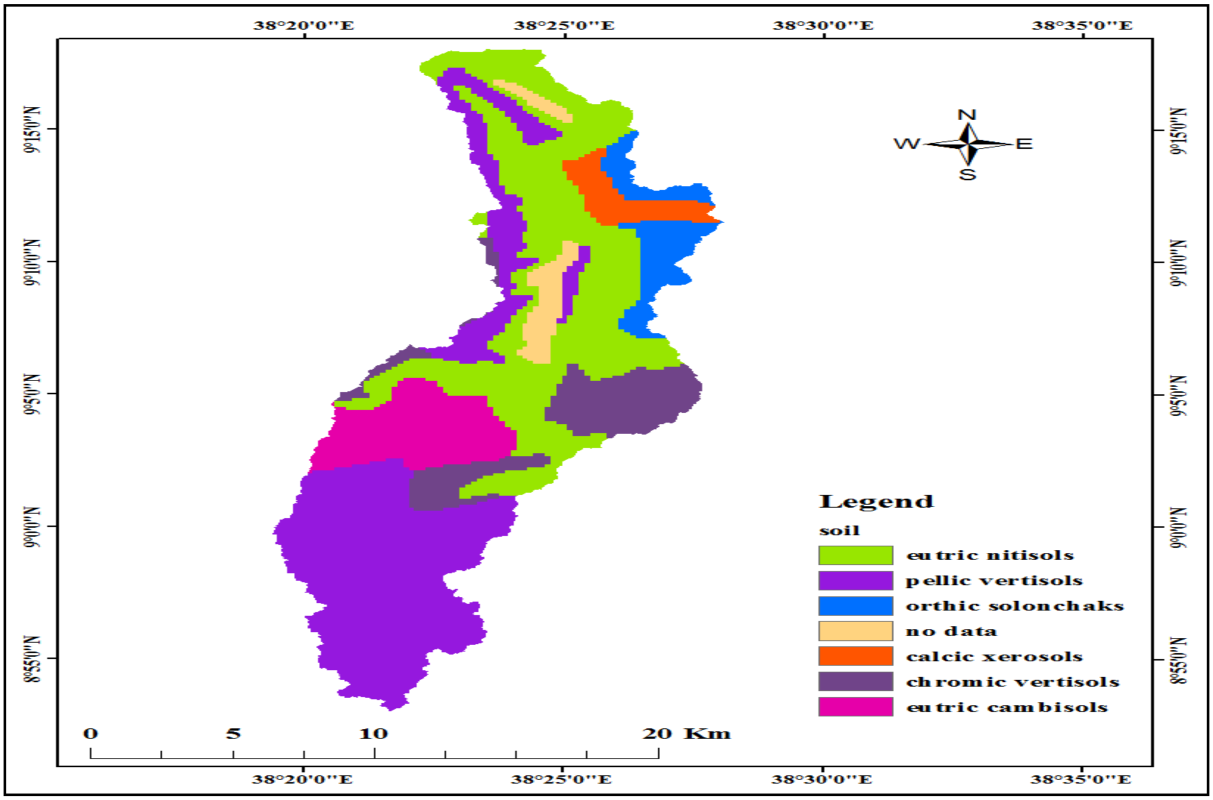


Figure: 3. 9 Barga watershed soil type map

3.1.7 Flood related facts of the Barga river watershed

Flood of the Barga River watershed is frequent within ten years highly affect six likes Horaa, Kimmoyyee, Inaaftu, Arabsaa, Dhibu and Ammaroo villages from Ejere Disaster Risk Management and Food Security Sector(EDRMFSS). The most highly affect the area is recorded start from 1977, 1986, 1989, 1991, 1996 1998,2000, 2001, 2003, 2006, 20011, 2018, and 2019 (EDRMFSS). From those recorded 1986, 1998, 2001, 2006, 2018, and 2019 the most worst period. According to MWIE (2018), the main cause of flooding in the area particularly east of Barga River was the rise of water level in river due to enter to Awash River and the slope area is flat. In one way or another, flooding has been a serious problem in the flat downstream areas of Barga Watershed. The (Figure 3.10) was the picture capture during the flooding time of the Barga River. In 2018, the total area inundated was over 2490 ha. The above mentioned have been suffering from flooding.

Figure: 3. 10 Flood Related facts of the Barga River (2018)

The 2018 flood event

The 2018 flood affected over 7110 households compared to that of the 1998 flood which affected about 6206 households (flood Alert, 2006). This year flood was the most sever of all the flood events experienced in the area so far. Due to the flood, 43,127 people (10% of the area population) were affected (UNOCHA, 2018). This figure accounts 5% of the affected population in Oromiya regional state (UNOCHA, 2018). The following image show the devastating 2018 flood events from its occurrence to the month when it gradually dries up.

Figure: 3. 11 flood of the study area in (2018)

The figure above shows sever is flooding in the area water overflow on the settlement areas and the agricultural and grazing lands around them. Over all compared with the earlier years the 2018 summer was so severe in terms of area coverage and property damage but the causalities to human life is minimal. For instance in 1998 taken away 1590 people life in which, 790 where women and 800 men respectively. Depending up on different flood causative factors the number of households displayed by its impact varies from year to year (Figure: 3.12).

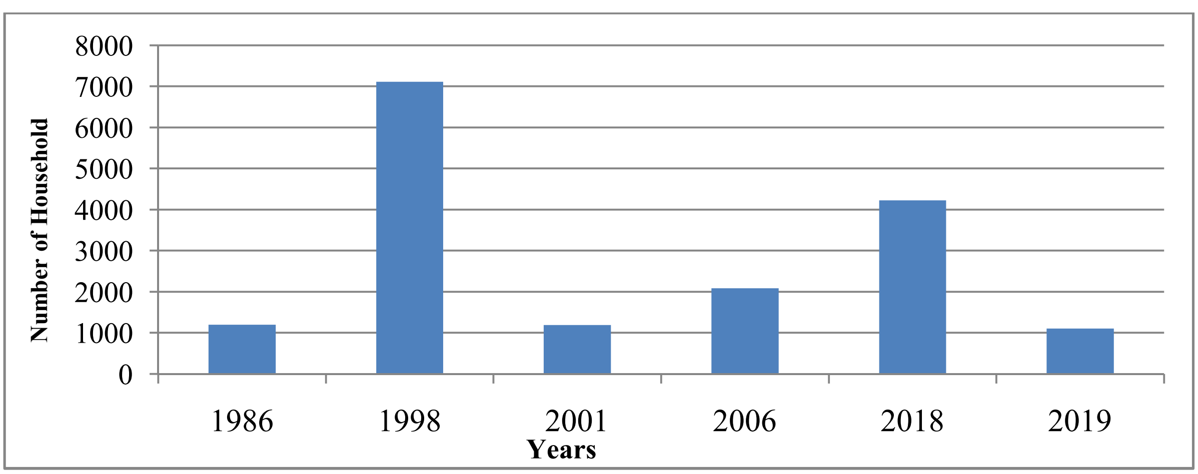


Figure: 3. 12 People which affected by flood watershed (EDRMFSS, 2018)

According to (EDRMFSS, 2018) flood severely affects six at adjacent to Barga River about 75811 people were affected and 5012 of were displaced from their homes (tables).

Table: 3. 2 Affected population in Barga watershed in 2018(EDRMFSS, 2018).

Kebeles Name	Total population			Affected Population			Displaced Population		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Horaa	1820	2004	3824	781	639	1420	290	300	590
Kimmoyyee,	2051	2150	4201	795	740	1535	320	320	640
Inaaftuu,	2650	2621	5271	360	350	790	122	150	272
Arraabsaa,	1365	1347	2712	985	930	1915	410	360	770
Ammaroo	15505	15890	31395	795	735	1530	320	340	660
Dhibu	13508	14900	28408	980	1050	2030	420	450	890
Total	36899	38912	75811	4696	4444	9140	1882	1920	2822

3.2 Materials

GPS was used to collect information on area critically affected by the 2018 flood and it is also use to collect information on training sites for populated area.

3.2.1 Software

Software used in this study is select based on the capability to work on the existing problems in achieving the predetermined objectives. Arctic 10.4.1 was used to delineate the watershed for which flood hazard analysis would be done. MS Excel was used for flood frequency analysis. IDRISI 32 software was used for calculate the weight of different factors that used to analysis the MCE method for flood Hazard map. The factor map development of soil type, slope, drainage density, geology, rainfall, elevation, flow accumulation, topographic wetness index, and land use land cover, reclassification, overlaying the factors map, weighting the flood hazard and risk map was carried out using Arc GIS 10.4.1 software package. The factors that are input to for multi-criteria analysis should be preprocessed in accordance to the criteria set to develop flood hazard analysis. So using Spatial Analyst and 3D Analyst extension, some relevant GIS analyses were undertaken to convert the collected shape files. The last software used XLSTAT 2015 for fill the missing data.

3.3 Data sources

In the study, data sources are categorized as primarily and secondary data sources. The primarily data sources are GPS and satellite image. While the secondary data sources are hydrological data, Existing topographic maps, different shape file and Digital Elevation

Model (DEM) which had (12.5 x12.5 m) spatial resolution is download from Alaska Satellite facilities website (https://search.asf.alaska.edu/8/30/2019) and used to express the elevation, orientation of the slope, to delineate the watershed, and to develop drainage pattern of the watershed, flow accumulation and topographic wetness index. Furthermore, existing census data that explained demographic characteristics of the societies are obtained from Ejere Health Center (EHC) and was be used in this study.

The spatial data like GPS data was collected from the watershed by data collectors and the researchers. Like wises, other georeferenced spatial data like to display which has the scale of 1: 50,000 was from Ethiopian Mapping Service Agency (EMSA), for verification of the satellite image and for creation of drainage pattern in the watershed. In addition, some of the spatial data like: Soil, geologic and stream daily discharge of (1975- 2012 year) was from Ministry of Water, Irrigation and Electricity (MWIE), climate data (1991-2018 Year) available was from National Meteorological Service Agency (NMA) and the DEM (12.5 x 12.5 m) special resolution was from Alaska Land facilities website.

The whole spatial as well as non-spatial data are integrate in digital form with geo-referenced framework in GIS environment to create spatial information for better decision making of flood controlling and reducing in the study area. The data that must be need for this study summarized in the following (Table 3.3).

Table: 3. 3 Summaries of collected data

Areas	Data	Data type	Scale	Data sources
Barga watershed	Hydrologic Data	Gauge level	Daily data	MWIE
	Daily Max Rainfall	Rainfall records	Daily data	NMSA
	Soil	Soil Type Shape File	1:500,000	MWIE
	Geology	Geology type shape file	1:500,000	MWIE
	Land use Land cover	LULC raster	1:500,000	EMA
	Ground Truth	Point data		Field survey
	Digital elevation model (DEM)	Raster data		Internet
	Population data	Point data		EHC

3.4 Methods of Data analysis

3.4.1 Multi criteria spatial decision support systems

The flood hazard analysis was computed using multi criteria evaluation (MCE). To run MCE, the selected factors were developed and weighted. All of these processes, the compilation of contributing factor maps, the overlaying of all maps (factors) and the calculation of flood hazard areas were obtained by using Weighted Overlay in Arc GIS Spatial Analyst tool. Therefore, the higher weight is the more influence a particular factor will have in the flood generation (Bedasa, *et al.,* 2018).

A decision is a choice between alternatives. The alternatives may represent different courses of action, different hypotheses about the character of a feature, different classifications, and so on. Broadly speaking a Decision Support System (DSS) is simply a computer system that helps you make a decision. DSS provide a means for decision-makers to make decisions on the basis of more complete information and analysis. Decision makers historically have indicated that inaccessibility of required geographic data and difficulties in synthesizing various recommendations are primary obstacles to spatial problem solving. Studies have shown that the quality of decisions (i.e., the ability to produce meaningful solutions) can be improved if these obstacles are lessened or removed through an integrated systems approach, such as a spatial decision support system (SDSS), particular and important types of DSS. SDSS refers to those support systems that combine the use of GIS technology with software packages for selection of alternatives of location for different activities.

In addition, multi criteria decision making (MCDM) and a wide range of related methodologies offer a variety of techniques and practices to uncover and integrate decision makers' preferences in order to solve "real-world" GIS-based planning and management problems. However, because of conceptual difficulties (i.e., dynamic preference structures and large decision alternative and evaluation criteria sets) involved in formulating and solving spatial decision problems, researchers have developed multi-criteria-spatial decision support systems (MC-SDSS).

Spatial Multi-criteria decision problems typically involve a set of geographically defined alternatives (events) from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria (Malczewski, 1996). A criterion is some basis for a decision that can be measured and evaluated. It is the evidence upon which an individual can be assigned to a decision set. Criteria can be of two kinds: factors and constraints. A factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. But a constraint serves to limit the alternatives under consideration. In many cases, constraints will be expressed in the form of a Boolean (logical) map: areas excluded from consideration being coded with and those open for consideration being coded with a 1. Multi-criteria evaluation (MCE) is most commonly achieved by one of two procedures. Each method is characterized by different levels of control over tradeoff between factors and the level of risk assumed in the combination procedure.

The first involves Boolean overlay, most simplistic type of aggregation, whereby all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection and union. The second is known as weighted linear combination (WLC) where in continuous criteria (factors) are standardized to a common numeric range, and then combined by means of a weighted average. The result is a continuous mapping of suitability that may then be masked by one or more Boolean constraints to accommodate qualitative criteria, and finally threshold to yield a final decision.

The weighted linear combination (WLC) aggregation method multiplies each standardized factor map (i.e., each raster cell within each map) by its factor weight and then sums the results. Since the set of factor weights for an evaluation must sum to one, the resulting suitability map will have the same range of values as the standardized factor maps that were used. This result is then multiplied by each of the constraints in turn to "mask out" unsuitable areas. All these steps could be done using either a combination of scalar and overlay, or by using the Image Calculator. In this thesis, WLC, which give us continuous level of hazard and risk maps in contrast to the Boolean sharp break two class values (hazard- risk/safe), is used.

Breaking the information down into simple pair wise comparisons in which only two criteria need be considered at a time can greatly facilitate the weighting process, and will likely produce a more robust set of criteria weights. A pair wise comparison method has the added advantages of providing an organized structure for group discussions, and helping the decision making group sharpen in on areas of agreement and disagreement in setting criterion weights. In the procedure for Multi-Criteria Evaluation using a weighted linear combination, it is necessary that the weights sum to one. In Satyr's technique, weights of this nature can be derived by taking the principal eigenvector of a square reciprocal matrix of pair wise comparisons between the criteria.

The technique used in this thesis and implemented in IDRISI GIS software is that of pair wise comparisons developed by Saaty's (1977) in the context of a decision-making process known as the Analytical Hierarchy Process (AHP) (J. Ronald Eastman, 2001). It is one of the multi-criteria decision-making techniques. In the procedure for Multi-Criteria Evaluation using a weighted linear combination, it is necessary that the weights sum to one. In Saaty's technique, weights of this nature can be derived by taking the principal eigenvector of a square reciprocal matrix of pair wise comparisons between the criteria. The comparisons concern the relative importance of the two criteria involved in determining suitability for the stated objective. Ratings are provided on a 9-point continuous scale

Spatial multi-criteria analysis is vastly different from conventional MCDM techniques due to inclusion of an explicit geographic component. In contrast to conventional MCDM analysis, spatial multi criteria analysis requires information on criterion values and the geographical locations of alternatives in addition to the decision makers' preferences with respect to a set of evaluation criteria.

This means analysis results depend not only on the geographical distribution of attributes, but also on the value judgments involved in the decision making process. Therefore, two considerations are of paramount importance for spatial Multi criteria decision analysis: (1) the GIS component (e.g., data acquisition, storage, retrieval, manipulation, and analysis capability); and (2) the MCDM analysis component (e.g., aggregation of spatial data and decision makers' preferences into discrete decision alternatives).

MC-SDSS offer a flexible, problem solving environment where the decision problem can be explored, understood and redefined; tradeoffs between multiple and conflicting objectives investigated; and priority actions set. In addition, MC-SDSS should have the ability to support both single-user and group decision-making processes. Systems in this category are termed MC-Group SDSS, and usually provide multiple-user/single-model and multiple-user/ multiple-model support.

To summarize, MC-SDSS tools offer unique capabilities for automating, managing, and analyzing single-user and collaborative spatial decision problems with large sets of feasible alternatives and multiple conflicting and incommensurate evaluation criteria

The objective of hazard assessment is to identify the factor that cause the flood, and overly the factors of flood hazard and risk, decide the weight of flood hazard and risk area predict probable emergency response in flood inundated map areas and predict the magnitude of discharge flood in the river in a specific future time period as well as its intensity and area of impact. Different types of hazard would require different mapping techniques. The importance lies in the easy understanding and clear intended purpose of the information generated. Flood hazard areas are usually divided according to severity (deep or shallow), type (quiet water or high velocity) or frequency. The flood assessment is very important in zoning of land use and the designing of engineering facilities (International Strategy for Disaster Reduction, 2004). Hazard assessments utilize formal procedures that include collection of primary data, monitoring of hazard and vulnerability factors, data processing mapping and social survey techniques (Susan, *et al.*, 1997).

The approach adopted in this study in order to reach the objectives of the study is reclassifying, weighting and run Multi Criteria Evaluation (MCE). The selected flood disaster causative factors in the analysis of flood hazard assessment on Barga river watershed are drainage density, flow accumulation, topographic wetness index, slope, elevation, land use, rainfall and soil. To run MCE, the selected factors were developed and weighted. Then weighted overlay technique was computed in Arctic 10.4.1 Model Builder to generate flood hazard map. The factors selected for use in flood hazard analysis of Barga River area based on quotation as well as the knowledge of past flood in the area being investigated. Generally the flood hazard map calculated by the following formula.

$$FHM = \sum_{i=1}^{n} W * f \qquad 3.1$$

Where FHM = Flood Hazard Map, W = weight, f = factors, and n = number of factors. Flood hazard model build by Arc GIS was shown as below.

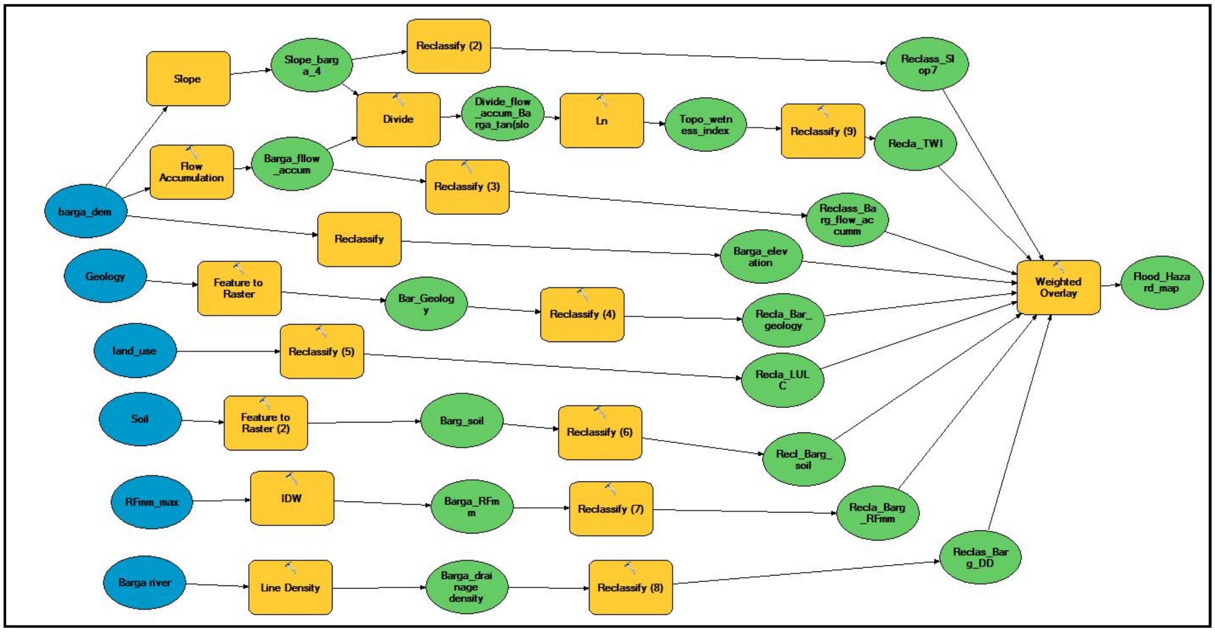


Figure: 3. 13 Flood hazard map building model

Flood Risk assessment requires an understanding of the causes of a potential disaster which includes both the natural hazard of a flood, and the vulnerability of the element at risk. According to Ken, (2002)the terms hazard, vulnerability, element at risk, and risk are defined as follows:

Hazard (H) means the probability of occurrence, within a specified period of time in a given area, of a potentially damaging natural phenomenon. Vulnerability (V) means the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude. Elements at risk (E population, land use) mean the dings and civil engineering works, economic activities, public services, utilities and infrastructure, etc., at risk in a given area. Risk (R) means the expected degree of loss due to a particular natural phenomenon Risk analysis can be defined as “a systematic use of available information to determine how often specified events may occur and the magnitude of their likely consequences” (Ken, 2002). Flood risk of the watershed was analyzed from the following general risk equation (Ken, 2002).

Risk = (Elements at risk)*(Hazard*Vulnerability) 3.2

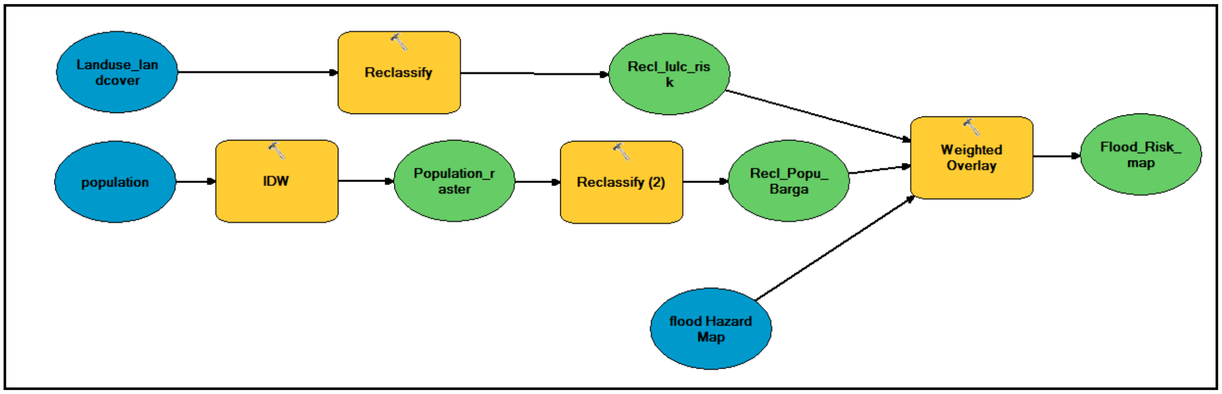


Figure: 3. 14 Flood risk map building model

The validation of flood hazard and risk was using the ground truth data which is collected during the field surveying of the flood affected area in different time. Spaticaly for this study flood affected area during 2018 and 2019 data was collected in september 2019 in form of point data was collected by researcher. The point location of flooding area was from six village of Ejere district and one village of Ada'a Barga district like Kimoye, Inaftu, Ammarro, Arrabsa, Dhibu, and Hora from Ejere district and Baso from Ada'a Barga. From each village two point location of the flooding area. This piont location was used for checking the validation of both flood hazard and risk map of Barga watershed.

3.4.2 Method of flood frequency analysis

The stream gauge is not at the outlet point therefore the discharge that gauge level must be transfer the outlet using the drainage area weighting area method. Drainage area weighting is a widely used technique in many cases where limited stream flow monitoring data are available. This method is most valid in situations where watersheds are of similar size, land use, and experience similar precipitation patterns. Discharge is estimated by drainage area weighting using the following equation (JD' Fenton DipCE, *et al.,* 2018).

$$Q_u = \left(\frac{A_u}{A_g}\right)^b (Q_g) \qquad 3.3$$

Where: $\mathbf{Q_u}$ ungauged discharge, $\mathbf{A_u}$ ungauged area, $\mathbf{A_g}$ Gauged area, **Qg** Gauged discharge **b-** If A_u>20% of the A_g ($0.8 \leq \frac{A_u}{A_g} \leq 1.2$) then n=1 to be used. The estimated discharge at the site must be within 10% of actual discharge (Seleshi, *et al.*, 2000)

Flood frequency analysis is one of the important studies of river hydrology. It is essential to interpret the past record of flood events in order to evaluate future possibilities of such occurrences. The estimation of the frequencies of flood is essential for the quantitative assessment of the flood problem. The knowledge of magnitude and probable frequency of such recurrence is also required for proper design and location of hydraulic structures and for other allied studies. The gauge data which are random variable follow the law of statistical distribution. After a detailed study of the distribution of the random variables and its parameters such as standard deviation, skewness and applying probability theory, one can reasonably predict the probability of occurrence of any major flood events in terms of discharge or water level for a specified return period.

Flood frequency analysis is done in this study by selecting annual maximum gauge levels at Barga watershed outlet site located in the watershed area. From many statistical distribution using L-moment method selection of best fit of the statistical distribution two methods of statistical distribution was selected i.e. logistic distribution and Person type III distribution were attempted by selecting peak gauge level data for 38 years (1975-2012 years) at the Barga watershed.

Person type III distribution:-Person type III distributions are discussed by Burkhardt and Prakash (1976). Linsley (1986) discussed the accuracy of flood estimates. It is one of the most widely used probability analysis for extreme values in hydrologic and meteorological studies for prediction of flood, rainfall etc. Person type III distributions defined a flood as the largest of the 365 daily flows and the annul series of flood flows constitute a series of largest values of flows. This study attempt to find out water levels at different return period using the Person type III distributions equation: where X_T = Value of variety with a return period 'T'and K_T = Frequency factor expressed as equation (3.4.1).

$$X_T = \hat{\alpha}\hat{\beta} + \hat{\gamma} + k_T\sqrt{\hat{\alpha}^2\hat{\beta}} \qquad (3.4)$$

$$K_T = \frac{2}{C_s}\left[\left\{\frac{C_s}{6}\left(2.326785 - \frac{C_s}{6}\right) + 1\right\}^3 - 1\right] \qquad (3.4.1)$$

Three of the more commonly used methods are considered here, namely, the method of moments (MOM), the maximum likelihood method (MLM) and the probability weighted moments method (PWM). The method of moments (MOM) is a natural and relatively easy parameter estimation method (Ramachandra, *et al.,* 2000). Where’$_s = \gamma$ Coefficient of skewness, m_2 -Sample moment, β – Moment ratio an α – Upper boundary d

$$\hat{\beta} = (2/C_s)^2 \tag{3.4.2}$$

$$\hat{\alpha} = \sqrt{(m_2/\hat{\beta})} \tag{3.4.3}$$

$$\hat{\gamma} = m'_1 - \sqrt{m_2\hat{\beta}} \tag{3.4.4}$$

General logistic: -The log-logistic distribution was compared to the GEV, LN (3), and person type III distributions by using data from Scotland by Ahmad *et al*. (1988). The log-logistic distribution was found to perform better than other distributions and hence was recommended for further analysis (Ramachandra, *et al.*, 2000).

$$\hat{x}_T = \hat{\varepsilon} + \frac{\hat{\alpha}}{\hat{K}}[1 - (T-1)^{-K}] \tag{3.5}$$

3.5 General flow chart

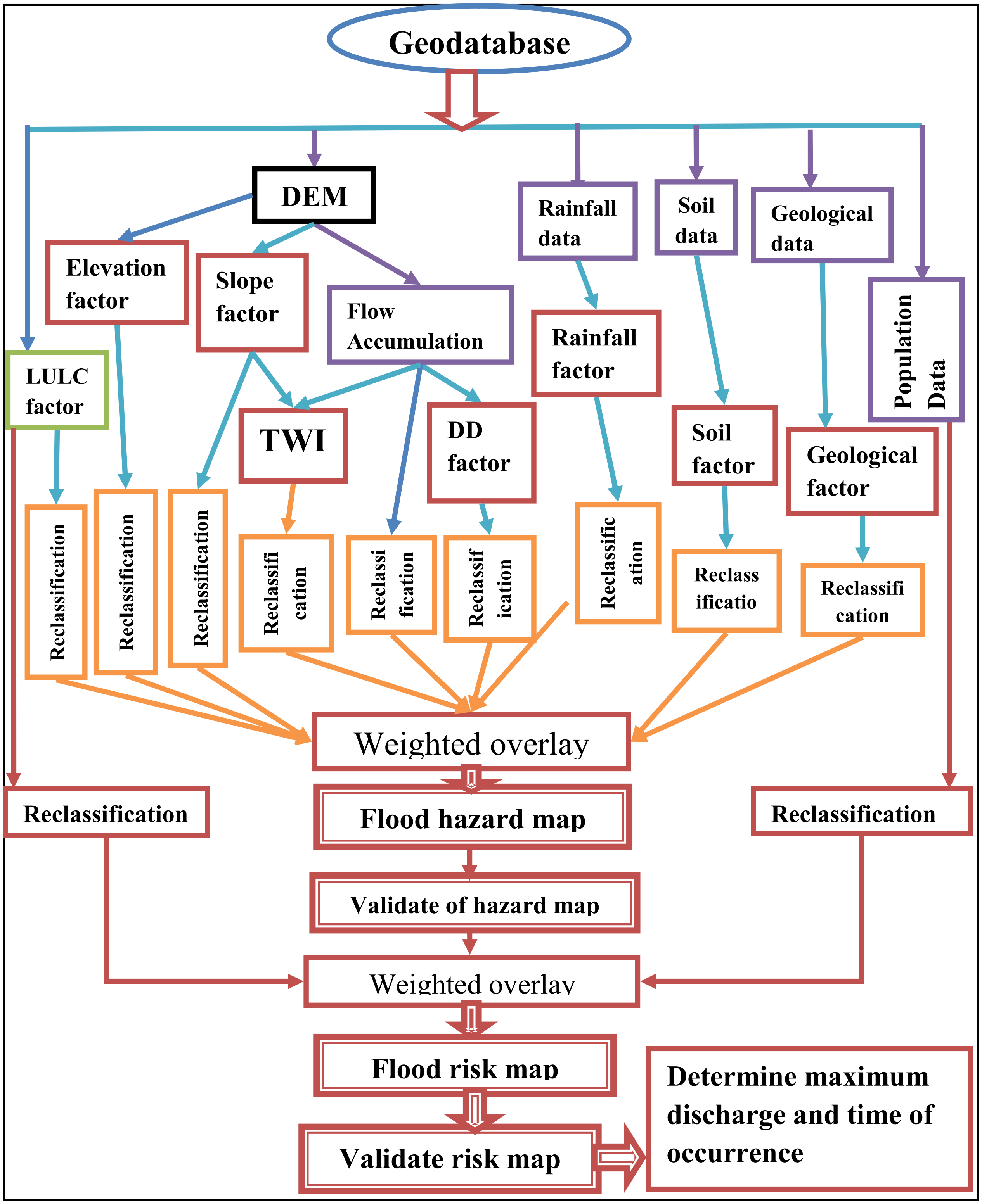


Figure: 3. 15 Flow chart

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Factors development for flood hazard map

Flood hazard map of the Barga was interrelated components of the environment were used as input data sets (factors) for the incidence of flood disaster. Main factors were identified for this study was nine (9): rainfall, drainage density, slope, elevation, soil, geology, flow accumulation, topographic wetness index and land use are main causative factors chosen for this particular study in Barga Watershed. The dataset for these factors were collected in different formats from different sources and processed through various steps and all changed into raster format and then reclassified and given weight according to their influence in causing flood. Therefore, the following factor developed for flood hazard mapping.

4.1.1 Slope factor

The inclination of the land from the horizontal plan is known as slope that can be evaluated with the ratio of vertical distance to the horizontal distance. This inclination of the earth surface is one of the factors for flooding. Slope has a great influence on flood hazard. The flatter the slope, the higher is the probability of the area to be flooded (Dessie, *et al.*, 2018). Slope has a great influence on flood hazard assessment because it governs the amount of surface runoff produced the precipitation rate and displacement velocity of water over the equip-potential surface (Yirga, 2016).

Therefore slope map was produced by the processing the DEM (12.5 x 12.5 m) resolution, using Arc GIS software, Spatial Analysis Tool, Surface Analysis, Slope. The Slope function could calculate the maximum rate of change between each cell and its neighbors. Every cell in the output raster had a slope value. The lower the slope value, the flatter the terrain and the higher the slope value the steeper terrain. The slope raster layer was further reclassified in five sub group using standard classification. The reclassified slope is given a value 1 to 5 with the higher value, 5 showing high influence in resulting very high flood rate, while the lower value, 1 showing very low influence in resulting very low flood rate. Therefore, an area with very low slope is ranked as 5 and an area with very high slope is ranked as 1and shown as (Figure 4.1).

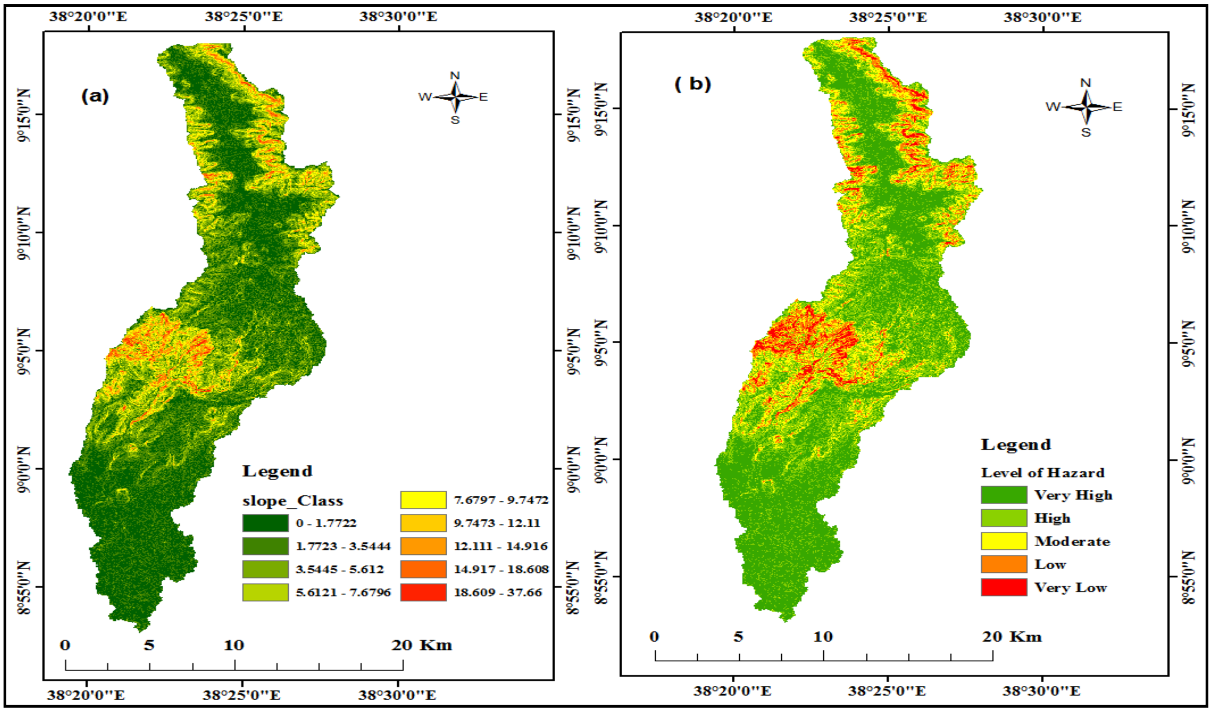


Figure: 4. 1 (a) Slope map and (b) Reclassified slope map

This classification scheme divides the range of attribute values into sub ranges that allow specifying the number of intervals while Arc GIS determines where the breaks should be add new values re-assigned in order of flood hazard rating. Area of reclassified depend on the level hazard was calculated by Arc GIS which is shown in (Table 4.1). This area was calculated from raster data form under spatial tool analysis there is zonal calculation tool under zonal calculation tool and has zonal statistics tool calculate the zone of the area with respect to level of hazard zone areas.

Table: 4. 1 Reclassified slope of Barga watershed in level of hazard

Slope (%)	Class	Ranking	Area		Level of Hazard
			Ha	%	
0 – 0.9	Flat plain	5	2906.531	9.160326	Very High
0.9– 6.4	Undulating Plain	4	23009.63	72.51795	High
6.4– 13	Undulating to Rolling	3	4974.797	15.67875	Moderate
13 – 23	Rolling to Hilly	2	825.6406	2.602118	Low
23.85– 37.36	Mountainous	1	12.96875	0.040873	Very Low

4.1.2 Soil factor

Different soil types have different capacities to infiltrate water. The soil factors influencing the rate of infiltration are: the total amount of pores (soil porosity), the particle size distribution and the structure of pores (grain size distribution), soil structures (size distribution and structure of aggregates) and organic matter content of the soil (Yirga, 2016). According to FAO (2001) the highest infiltration rates or water holding capacity are measured on Pellic Vertisols that have a considerable shrink/swell capacity. Eutric Cambisols and Chromic Vertisols are medium-textured and have a good structural stability, a high porosity, good water holding capacity and good internal drainage. Eutric Nitisols are normally free from noxious levels of soluble salts. Orthic Solonchanks high proportion of large pores that account for their good aeration, rapid drainage and low moisture holding capacity. Very low water holding capacity and high permeability to water make most Calico Xerosols sensitive to flooding the characteristics of each soil group are analyzed based on hydrologic soil grouping system.

Accordingly, the soil group of the study area was grouped into six general classes and converted to raster format. Further, the soil raster layer group was reclassified into five groups and new values reassigned in order of their flood hazard rating. Soil type that has very high capacity to generate very high flood rate is ranked to 5 and the one with very low capacity in generating flood rate is ranked to 1; therefore, Pellic Vertisols are ranked to 5, Chromic Vertisols and Eutric Cambisols are ranked to 4, Eutric Nitisols are ranked to 3, Orthic Solonchanks are ranked to 2, and Calico Xerosols are ranked to1. Therefore reclassified map of the watershed was shown as (Figure 4.2).

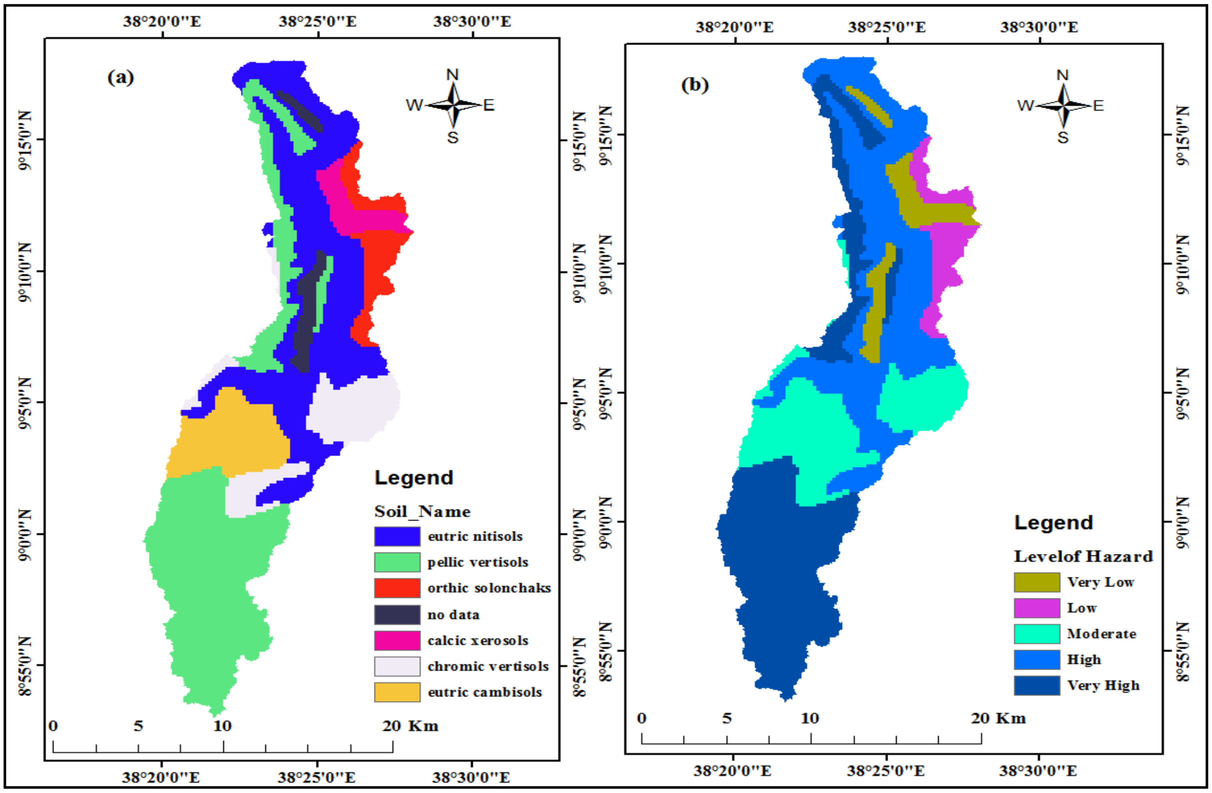


Figure: 4. 2 (a) Soil map and (b) reclassified soil map

The study area has different soil type that was reclassified depend their infiltration rate. The area of reclassified soil factor and percent of the reclassified are were discussed in (Table 4.2).

Table: 4. 2 Reclassified soil of Barga watershed in level of hazard,

Soil type	Ranking	Area		Level of Hazard
		Ha	%	
Calcic Xerosols	1	2151.984	6.782309	Very Low
Orthic Solonchanks	2	1801.25	5.676916	Low
Eutric Nitisols	3	10127.984	31.9199	Moderate
Chromic Vertisols and eutric Cambisols	4	6336.031	19.96898	High
Pellic Vertisols	5	11312.125	35.6519	Very High

4.1.3 Elevation factor

Elevation is the height of land that is above sea level or the vertical distance between a standard reference point, such as sea level, and the top of an object or point on the Earth, such as a mountain. There are different elevations on the earth surface above the reference point or mean sea level. The difference elevation has factor that play an important role in flood. Elevation, as an intensifying factor, plays an important role in flood severity and for the determination of a flood prone area (Bedasa, *et al.*, 2018).

The elevation raster was derived from the DEM (12.5 x12.5 m) resolution using the Arc GIS Spatial Analyst extension of surface module, which enabled to classify the area according to the height above m.s.l. The elevation function could calculate the maximum rate of change between each cell and its neighbors. Every cell in the output raster had an elevation value. The lower elevation value, flatter terrain and the higher the elevation value undulating terrain. The elevation raster layer was further reclassified in five sub group using standard classification schemes namely equal interval. The reclassified elevation is given a value 1 to 5 with the higher value,5 showing high influence in resulting very high flood rate, while the lower value,1 showing very low influence in resulting very low flood rate. Therefore the elevation map and reclassified map of the elevation factor was show as (Figure 4.3)

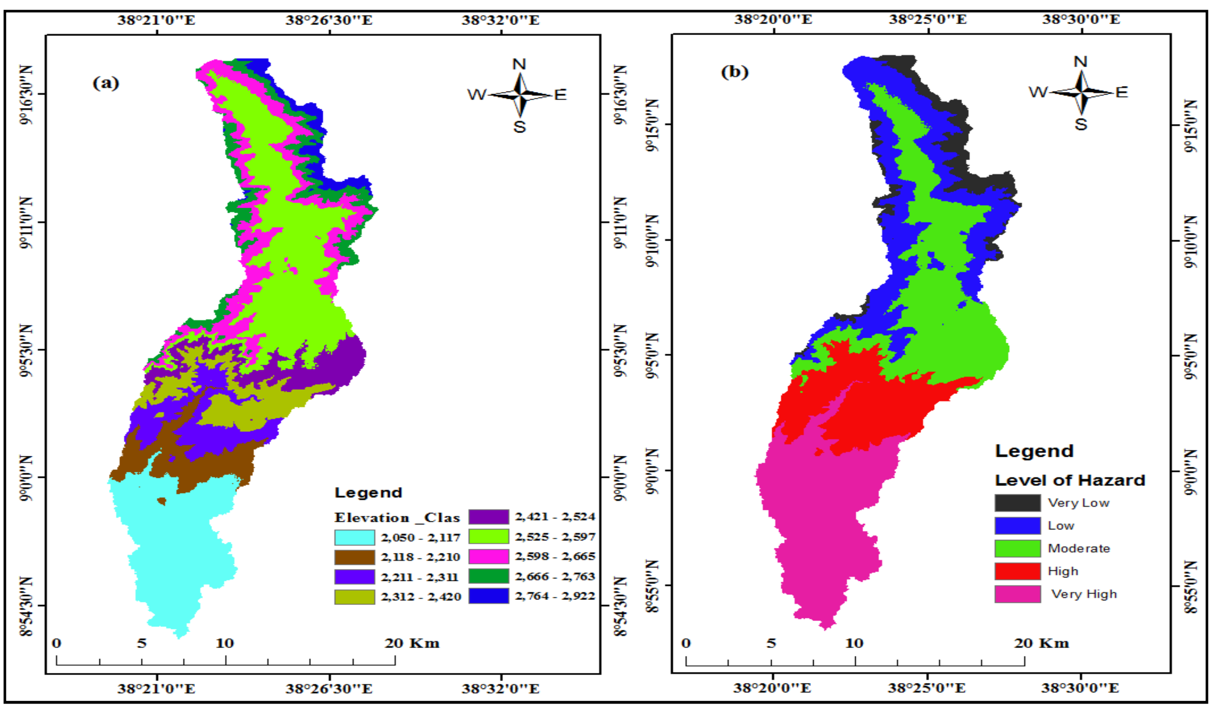


Figure: 4. 3 (a) Elevation map and (b) Reclassified elevation map

This classification scheme divides the range of attribute values into equal sized sub ranges that allow specifying the number of intervals while Arc GIS determines where the breaks should be add new values re-assigned in order of flood hazard rating. The area of flood hazard level in hectare and its percent of the total area of watershed of elevation factor were discussed in table (4.3).

Table: 4. 3 Reclassified Elevation Barga watershed in level of hazard

Elevation (m)	Ranking	Area		Level of flood Hazard
		Ha	%	
2050 – 2228	5	5144.32	18.48	Very High
2228 – 2402	4	3536.37	12.70	High
2402 – 2576	3	3631.67	13.05	Moderate
2576 – 2750	2	11952.06	42.93	Low
2750 – 2922	1	3573.19	12.84	Very Low

4.1.4 Drainage density factor

Drainage density (DD) a fundamental concept in hydrologic analysis is defined as the ratio of the length of drainage per basin area. DD is controlled by permeability, adorability of surface materials, vegetation, slope and time. Greater drainage density indicates high runoff for basin area along with erodible geologic materials, and less prone to flood.(Yirga, 2016). DD is an inverse function of infiltration.(Ajin, *et al*., 2013). DD is an important physical factor that greatly contributes to flood disaster. The stream order is also important in the evaluation of flood's impact over an area occurrence.

The drainage of the study area is derived from DEM (12.5 x 12.5 m) and further rectified in GIS environment and using the Spatial Analyst extension line density module was used to compute drainage density of the study area. Line density module calculates a magnitude per unit area from plotline features that fall within a radius around each cell. The density layer is further reclassified in five sub group using standard classification schemes namely Equal Interval. The reclassified drainage density is given a value 1 to 5 with the higher value,5 showing high influence in resulting very high flood rate, while the lower value,1 showing very low influence in resulting very low flood rate. Therefore, an area with very low drainage density is ranked as 1 and an area with very high drainage density is ranked as 5. This classification scheme divides the range of attributer value into equal–sized sub rages that allow specifying the number of intervals while Arc GIS determines where the breaks should be add new values re-assigned in order of flood hazard rating. The reclassified map of drainage density was shown as (Figure 4.3).

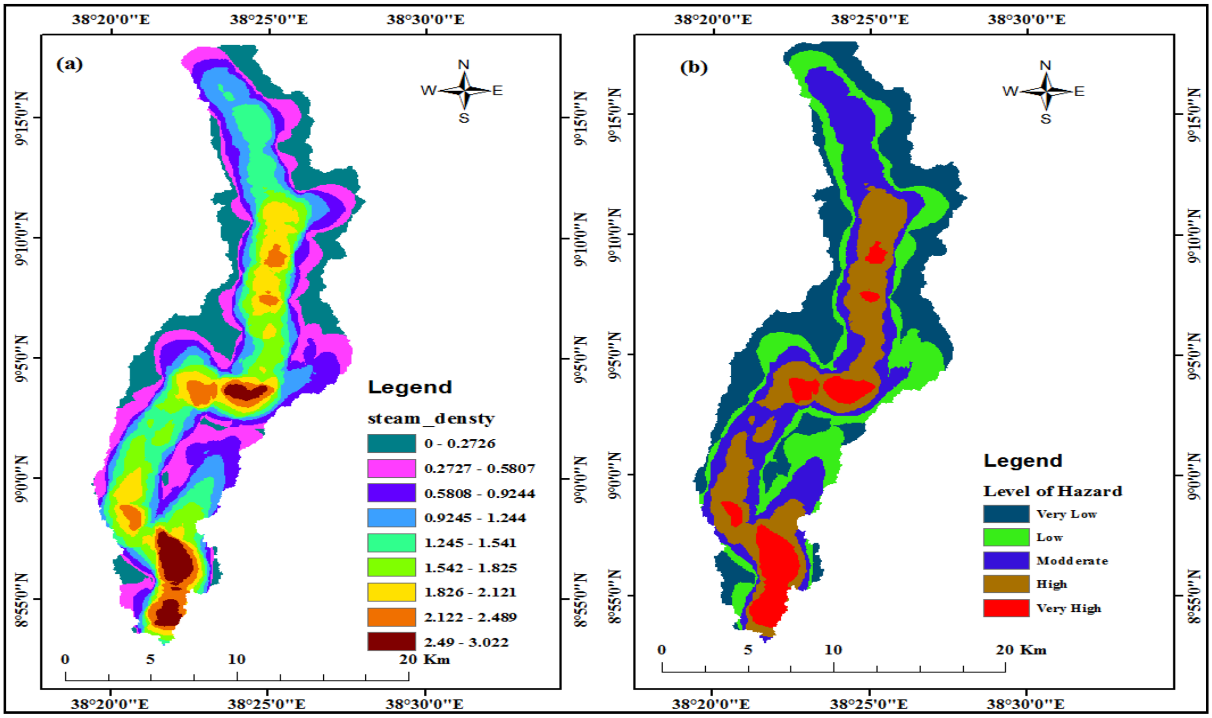


Figure: 4. 4(a) Drainage density map and (b) Reclassified drainage density map

The flood hazard level area the watershed in hectare and percent of the total area is motioned in the (Table 4.4).

Table: 4. 4 Reclassified DD of Barga watershed in level of the hazard

Drainage density (Km/km^2)	Class	Ranking	Area		Level of Hazard
			Ha	%	
0 - 0.604	Very low dense	1	9128.734	28.768	Very Low
0.604 - 1.209	Low dense	2	6677.593	21.044	Low
1.209 - 1.813	Moderate dense	3	7262.797	22.888	Moderate
1.813 - 2.418	High dense	4	6294.719	19.837	High
2.418 - 3.022	Very high dense	5	2367.597	7.461	Very High

4.1.5 Flow accumulation

Flow accumulation is an important parameter in defining flood hazard. Accumulated flow sums the water flowing down-slope into cells of the output raster. High values of accumulated flow indicate areas of concentrated flow and consequently higher flood hazard (Nerantzis, *et al*., 2015). The flow accumulation is the most important factor in delineating flood susceptibility areas. High values of accumulated flow indicated regions of concentrated flow and eventually prone to higher flood hazard (Lappas, *et al*., 2019).

Flow accumulation was derived from the flow direction raster. In the flow accumulation raster, each cell contains information on the number of cells that flow into it which means that each cell is also a discharge profile. In this sense, an increase in flow accumulation should reflect an increase in flood susceptibility. The classes of flow accumulation raster were defined in order that they best correspond to the vector layer of a river network used for creating the hydrological correct DEM (12.5 x12.5 m) resolution. It was reclassified depend on the Volume water concentrated in each cell. The cell which has more volume of water was classified under highly flooded and the vice verse. Flow accumulation of Barga watershed derived from DEM was reclassified into five classes. That was from very low to very high and it was shown on (Figure 4.5). The flow accumulation layer was further reclassified in five sub group using standard classification schemes namely Equal Interval. The reclassified drainage density is given a value 1 to 5 with the higher value,5 showing high influence in resulting very high flood rate, while the lower value,1 showing very low influence in resulting very low flood rate.

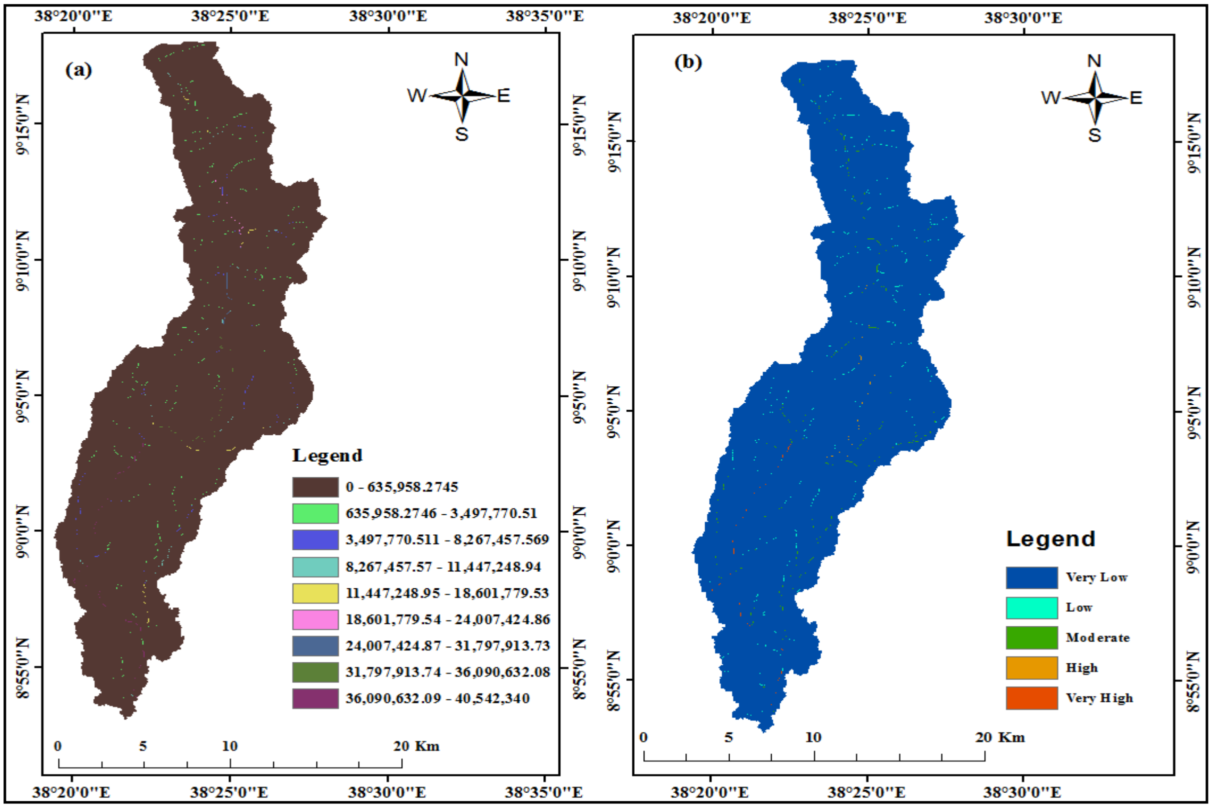


Figure: 4. 5 (a) Flow accumulation map and (b) Reclassified flow accumulation map

The area of the flow accumulation watershed reclassified depend on the flood hazard level was shown in (Table 4.5). It was in hectare and the percent of the total area in hectare of the flood hazard level.

Table: 4. 5 Reclassified flow accumulation Barge watershed in level of the hazard

Water in volume (m^3)	Class	Ranking	Area		Level of hazard
			ha	%	
0 - 92,037.27059	Very low volume	1	31677.3	99.83529	Very low
92,037.2706 - 429,507.2627	Low volume	2	8.9375	0.028168	Low
429,507.2628 - 966,391.3412	Moderate volume	3	16.07813	0.050672	Moderate
966,391.3413 - 1,480,266.102	High volume	4	14.20313	0.044763	High
1,480,266.103 - 1,955,792	Very High volume	5	13.04688	0.041119	Very high

4.1.6 Topographic wetness index

The Topographic Wetness Index (TWI) was developed by Bevin and Kirby (1979) combining the upstream contributing area per unit slope and is mostly used to quantify topographic control on hydrological processes and distribute the soil moisture in a given area. The TWI is given by the equation: TWI= $\ln(\alpha/\tan\beta)$ where, a the upslope contributing area (flow accumulation raster map for the corresponding DEM) $\tan\beta$ the slope angle (the slope raster map in degrees for the corresponding DEM) High values represent drainage depressions (lowlands with low slope gradient) with wet ground while low ones represent crests and ridges (highlands with high slope gradient). The higher value of TWI the more susceptible areas to flooding (Lappas, *et al*., 2019).

TWI of the Barga watershed was derived from the slope and flow accumulation of the watershed. Slope of the watershed was in degree which is from DEM (12.5 x 1.5 m) resolution and the flow accumulation also from flow direction of each cell. Then the natural logarithmic ratio of flow accumulation to tangent of the slope in degree was equal to TWI. The TWI layer was reclassified depend on the numerical value which is from the above description. The area which has high value of classified as very high and the area which has low value was consider as very low for susceptible to flood hazard. Very high consider as 5 and the very low of hazard was considered as 1and shown as (Figure 4.6).

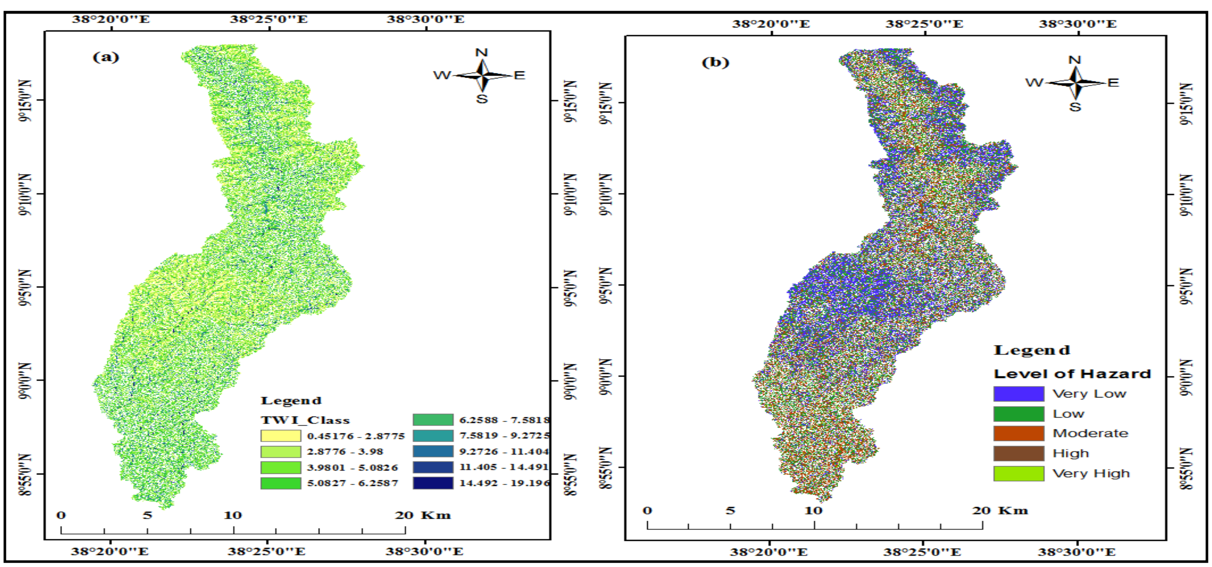


Figure: 4. 6 (a) Topographic wetness index map and (b) Reclassified topographic wetness index map

The area of the topographic wetness index watershed reclassified depend on the flood hazard level was shown in (Table 4.6).

Table: 4. 6 Reclassified area of topographic wetness index factor in hectare and percent of the area

TWI	Class	Ranking	Area		Level of hazard
			ha	%	
0.452 – 1.077	Very low wetness	1	226.7656	1.564096	Very low
1.077 – 2.399	Low wetness	2	9115.219	62.87143	Low
2.399 – 5.446	Moderate wetness	3	4778.719	32.9608	Moderate
5.446 – 10.73	High wetness	4	340.0781	2.345659	High
10.73 – 19.94	Very high wetness	5	37.40625	0.258006	Very high

4.1.7 Geology

The geology of flood hazard areas is an important criterion, because it may amplify/extenuate the magnitude of flood events. Permeable formations favor water infiltration, through flow and groundwater flow. On the contrary impermeable rocks, such as crystalline rock, favor surface runoff (Nerantzis, *et al*., 2015). According to Daniel (2010)Transitional and sub alkaline Basalt are medium-textured and have a good structural stability, a high porosity, good water holding capacity and good internal drainage. Permeable and basaltic formations favor groundwater infiltration, whereas impermeable ones, such as crystalline rocks, favor surface runoff. In the geological map the geological formations were considered and ranked based on the hydraulic conductivity (Lappas, *et al*., 2019).

Transitional and Alkaline basalt have a high proportion of large pores that account for their good aeration, rapid drainage and low moisture holding capacity. Ignimbrite has a very low water holding capacity and high permeability. The study area has three geology formations those are Transitional basalt are assumed to have a high flooding capacity, Alkaline basalt is assigned as moderate and Ignimbrite is assumed to have a low flooding capacity Therefore, Transitional basalt ranked as 3, Alkaline basalt ranked as 2 and Ignimbrite also is ranked as 1. Therefore reclassified of the geology was shown as (Figure 4.7).

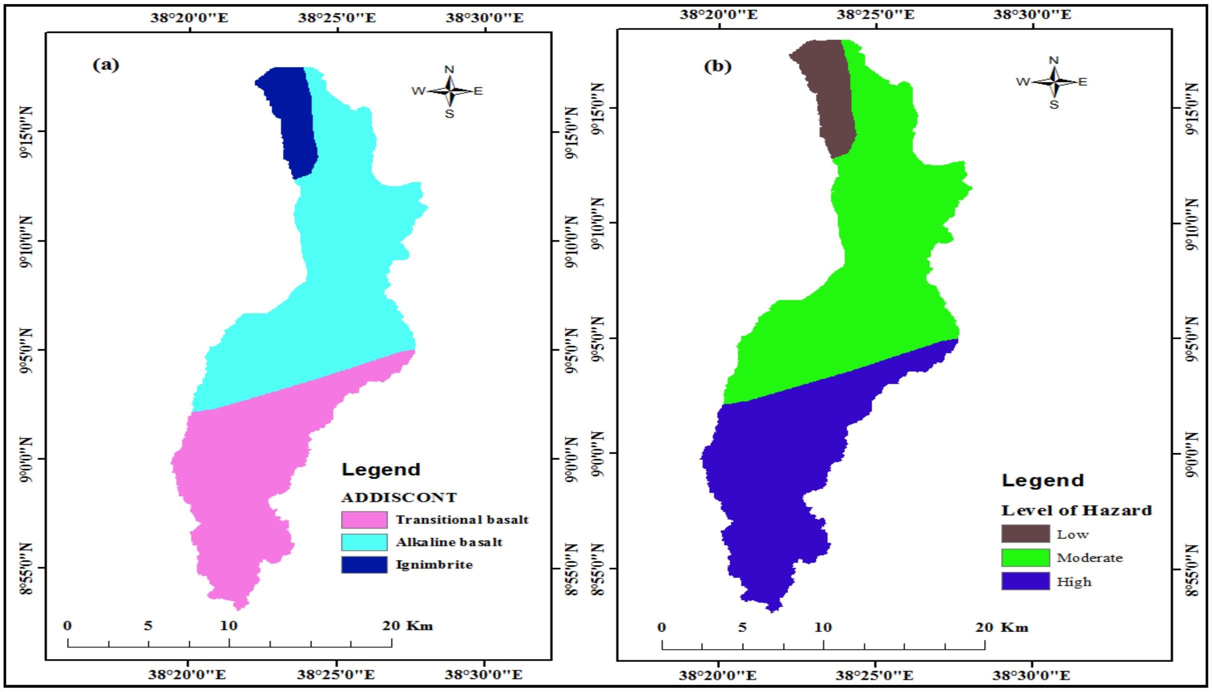


Figure: 4. 7 (a) Geology and (b) Reclassified geology map

The geology reclassified by considering the water holding capacity and level of infiltration. Reclassified geology map area in hectare and the percent of the total area was discussed in (Table 5.7).

Table: 4. 7 Reclassified geology, its area and the percent of the area

Class	Ranking	Area		Level of Hazard
		ha	%	
Ignimbrite	1	2071.828	6.69855	Low
Transitional and alkaline Basalt	2	17068.16	55.18407	Moderate
Transitional and Sub-alkaline basalt	3	11789.52	38.11738	High

4.1.8 Rain fall factor

Heavy rain falls are one of the main flood-triggering causes. Both the local and regional rainfalls were integrated due to the limited size of the study area. According to Getahun, *et al*.,(2015) identify that the main source of recharges for the vast groundwater system is the rainfall on the highlands during the rainy season. The major recharge occurs in the north-eastern, eastern highlands and upper basin, where annual rainfall is high. These aquifers are recharged the streams that originate from the eastern highlands. Seasonal floods occur in summer and the highland's fractured volcanic cover is favorable for groundwater recharge.

The rain falls a point data collected at five stations within the study area. The data limited is of twenty eight years of monthly total rainfall. From this data annual average was calculated for each station then interpolated to Inverse Distance Weight (IDW) and then converted to raster layer which was finally reclassified into five class's using Equal Interval. The reclassified rainfall is given a value 1 to 5 with the higher value,5 showing high influence in resulting very high flood rate, while the lower value,1showing very low influence in resulting very low flood rate. Therefore, an area with very high rainfall is ranked as 5 and an area with very low rainfall is ranked as 1. Accordingly, the raster map and the reclassified map of rainfall data (Figure: 4.8).

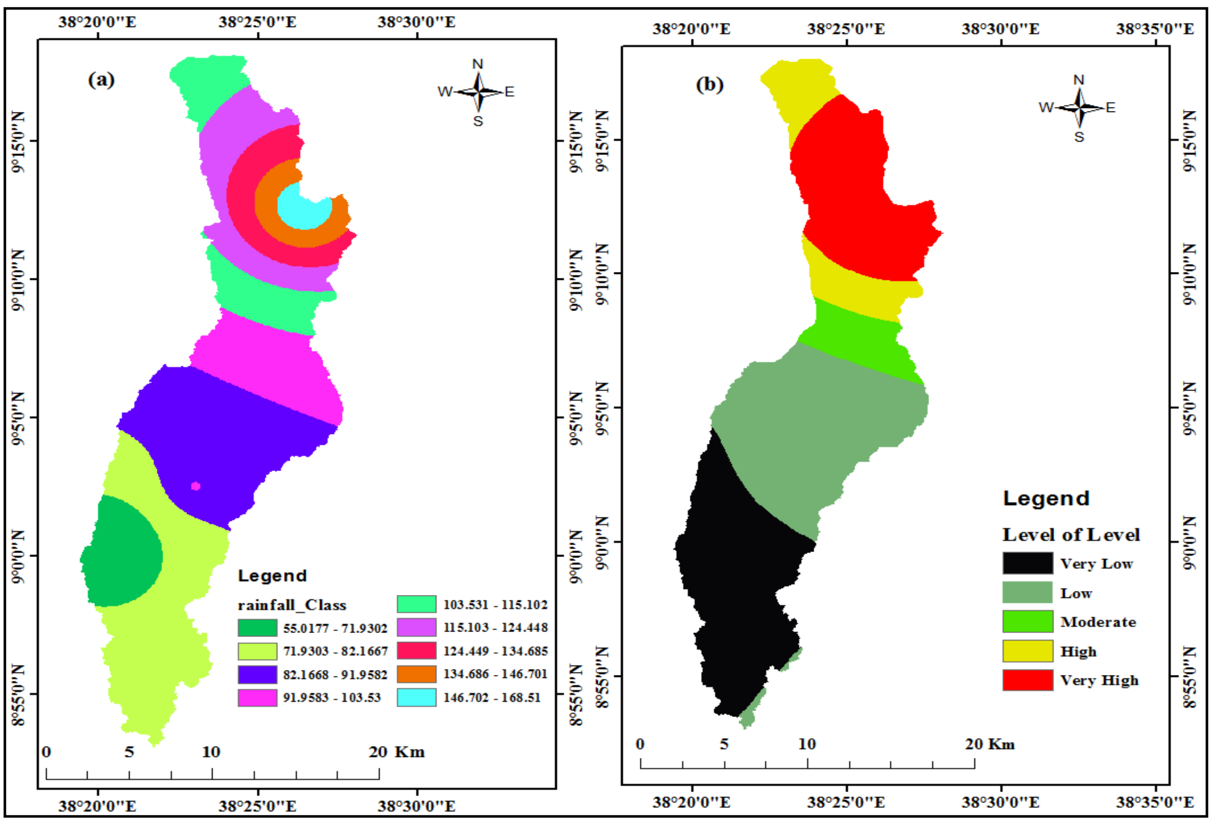


Figure: 4. 8 (a) Rainfall and (b) Reclassified rainfall map

The reclassified area interpolated density of point data rainfall is depend level hazard. Interval of the reclassified, its area and the percent of the total area is shown in (Table 4.8).

Table: 4. 8 Reclassified RF of Barga watershed in level of hazard,

Rain fall (monthly mm)	Ranking	Area		Level of Hazard
		ha	%	
54.967- 68.919	1	11513.30	37.11	Very Low
68.919 - 87.191	2	4194.22	13.52	Low
87.191 - 111.124	3	7797.94	25.13	Moderate
111.124 - 142.470	4	2158.30	6.96	High
142.470 - 166.402	5	5360.98	17.26	Very High

4.1.9 Land use land cover factor

Land use/cover change as one of the most prominent component in the hydrological processes of a given area it is important to evaluate the changes that undergone in a given catchment so as to understand the hydrological behavior of the catchment (Yonas, 2015). According to Kebede (2012) state that land covers (shrub land, wood land, grass land) of the upland sites and the flood plain area is decreased.

Therefore, there is high soil erosion in the upstream and sediments and dissolved substances cumulatively called river load deposited in the river channels and on adjacent flood plains in downstream of the major rivers. Land use of the study area was reassigned by categorizing land use types using query builder into five general classes and converted to raster layer. Further the existing land use type of the area was reclassified into five groups in order of their capacity to increase or decrease the rate of flooding. Accordingly, swampy land use type has the capacity to increase flood rate in the area, and hence, is ranked to 5, cultivated land is ranked to 4, woodland is ranked to 3, dense woodland is ranked to 2 and forest land has very low capacity to generate flood and is ranked to 1.

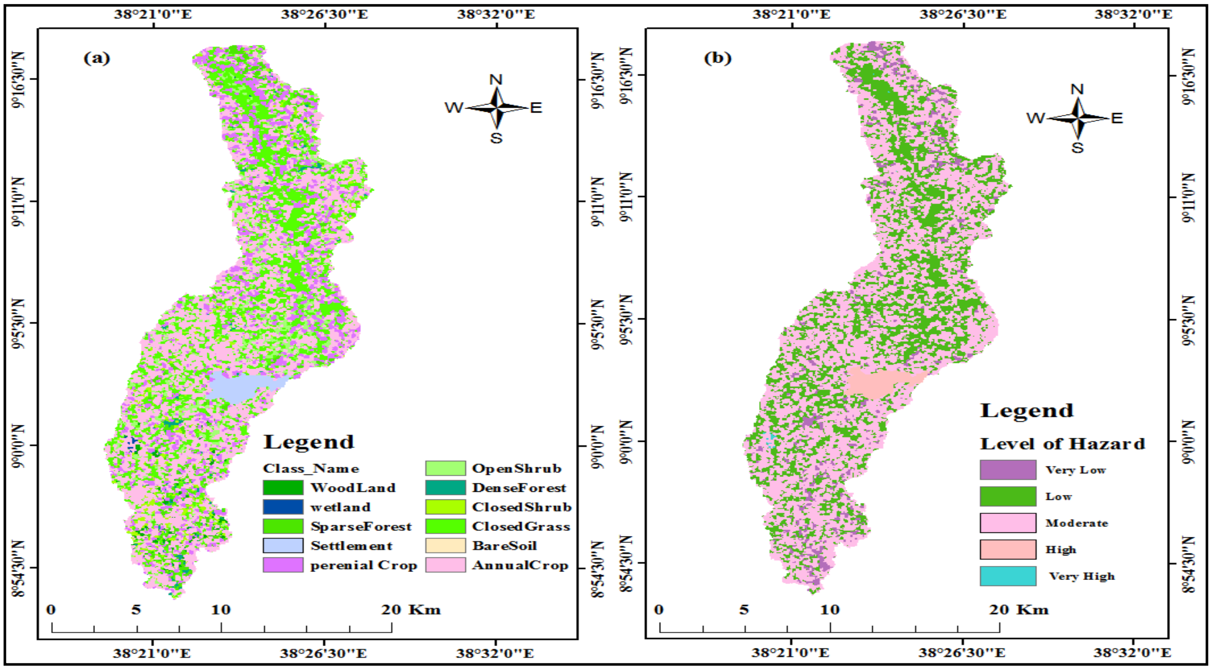


Figure: 4. 9 (a) LULC and (b) Reclassified LULC map

Land use land cover change as one of the most prominent component in the hydrological processes of a given area it is important to evaluate the changes that undergone in a given catchment so as to understand the hydrological behavior of the catchment. The LULC of the watershed was reclassified depend on the level flood hazard. The area of watershed reclassified and percent were discussed in (Table 4.9}.

Table: 4. 9 Reclassified LULC of Barga watershed in level of hazard,

Class	Ranking	Area		Level of Hazard
		ha	%	
Forest	1	1614.156	5.086116	Very Low
Shrubs	2	10647.77	33.55051	Low
Agriculture	3	18709.78	58.95347	Moderate
Settlement	4	738.1875	2.325988	High
Wetland	5	26.625	0.083894	Very High

4.2 Flood Hazard Map

The flood hazard map of the Barga watershed was the combination of factors were reclassified before, in the data model that was raster layer with a resolution of (12.5 x 12.5 m) cell size, and then combined by means of a weighted overlay Analysis. In Barga Watershed using GIS, a weighted Linear combination (WLC) was used where the raster layers are combined by means of Weighted Overlay. In order to show the importance of each factor as compared to others in resulting flood hazard Eigen Vector is used to weigh the standardized raster layers.

Weight of the factors was computed in IDRISI 32 software. It was calculated with the couple comparison matrix file of the factors in a comparison a point continuous scale. Before add to the IDRISI in Arc GIS has some steps first all parameters must be prepared in raster form then goes to conversion tool and change from raster to ASCII format then imports all factors in new folder of the IDRISI 32, and goes to modeling tools after that was displayed model deployment tools and weight AHP at the last arrange of the parameter and fix the weight of the parameter in diagonal matrix form in (Table 4.10) calculated each weight of all factors. The sequence of each factors depending on the area under very high level of hazard.

Table: 4. 10 Factors matrix developed using IDRISI software

Factors	Slope	Elevation	Soil	D/ density	F/accum ulation	TWI	Rainfall	Geology	LULC
Slope	1								
Soil	1/2	1							
Elevation	1/2	1/2	1						
D/ density	1/3	1/3	1/2	1					
F/accumul ation	1/5	1/3	1/2	1/2	1				
TWI	1/5	1/3	1/3	1/2	1/2	1			
Rainfall	1/7	1/5	1/3	1/3	1/2	1/2	1		
Geology	1/5	1/5	1/3	1/3	1/2	1/2	1	1	
LULC	1/3	1/3	1/3	1/3	1/2	1/2	1/2	1	1

Eigen vector weights of each factors; slope, elevation, soil, drainage density, flow accumulation, topographic wetness index, rainfall, geology, and land use land cover are 0.2830, 0.2061, 0.1418, 0.1076, 0.0803, 0.0623, 0.450, 0.0404, 0.0434 respectively and the consistency ratio of the matrix is 0.03 and it was acceptable.

The computed Eigenvector of weighted is used as a coefficient for the respective factor maps to be combined in Weighted Overlay analysis in Arc GIS environment for Flood hazard assessment.

Table: 4. 11 Weight of factors

Factors	**Weight %**
Slope	28
Soil	20
Elevation	14
Drainage density	10
Flow accumulation	8
Topographic witness index	6
Rainfall	5
Geology	4
Land use land cover	5

The factors of the flood hazard map have some sub factors those were summarized in the (Table: 4.12). Those sub factors is reclassified in depend on the level of hazard in the watershed of the Barga River. The level of flood hazard which summarized in (table 4.12) does 5 is represent very high, 4 represent high, 3 represent moderate, 2 represent low and 1 represent very low.

Table: 4. 12 Weight of factors flood hazard ranking and interval for Barga River (Hazard Analysis)

Factors	Weight	Sub_Factors	Ranking
Slope (%)	0.2830	0 – 0.9 0.9– 6.4 6.4– 13 13 – 23 23.85– 37.36	5 4 3 2 1
Soil (based on drainage capacity)	0.2061	Calcic Xerosols Orthic Solonchanks Eutric Nitisols Chromic Vertisols Pellic Vertisols	1 2 3 4 5
Elevation (m)	0.1418	2050 - 2224.4 2224.4 - 2398.8 2398.8 - 2573.2 2573.2 - 2747.6 2747.6– 2922	5 4 3 2 1
Drainage(Km/Km^2)	0.1076	0 - 0.604 0.604 - 1.209 1.209 - 1.813 1.813 - 2.418 2.418 - 3.022	1 2 3 4 5
Flow accumulation (m^3)	0.0803	0 - 92,037.27059 92,037.2706 - 429,507.2627 429,507.2628 - 966,391.3412 966,391.3413 - 1,480,266.102 1,480,266.103 - 1,955,792	1 2 3 4 5
Topographic wetness index	0.0623	0.452 – 1.077 1.077 – 2.399 2.399 – 5.446 5.446 – 10.73 10.73 – 19.94	1 2 3 4 5
Geology (based on water observation capacity)	0.0404	Transitional basalt Alkaline basalt Ignimbrite	3 2 1
Rain fall (mm)	0.0463	54.967- 68.919 68.919 - 87.191 87.191 - 111.124 111.124 - 142.470 142.470 - 166.402	1 2 3 4 5
Land Use (Level of flood abstraction)	0.0434	Forest Shrubs Agriculture Settlement Wetland	1 2 3 4 5

After the determination of the weights of the factors, a multi-criteria evaluation is used by utilizing the specific weights for each factor, to create the flood hazard map after superimposing the thematic maps with different weights in a GIS environment, the result is a flood hazard map showing the most vulnerable areas to flooding within the Barga watershed, the results of this stage of analysis are shown in (Figure 4.10). Flood hazard analysis was done by computing weighted overlay of rainfall (Rf), drainage density (Dd), slope (Sl), soil (St), land use (Lu), geology (G), flow accumulation (Fa), and topographic wetness index (TWI)and elevation (E) factors. Generally flood hazard map was calculated using equation (3.1).

$$FHM = 0.28*Sl + 0.20*St + 0.14*E + 0.10*Dd + 0.08*Fa + 0.06*Twi + 0.05*Rf + 0.04*G + 0.05*Lu$$

The flood hazard map (Figure: 4.10) shows that about 30853.94 ha of the total watershed area, from this area10.09%, 22.34%, 28.18%, 20.31%, 19.06% of the study area was subjected to very low, low, moderate, high and very high flood hazards severity classes, respectively.

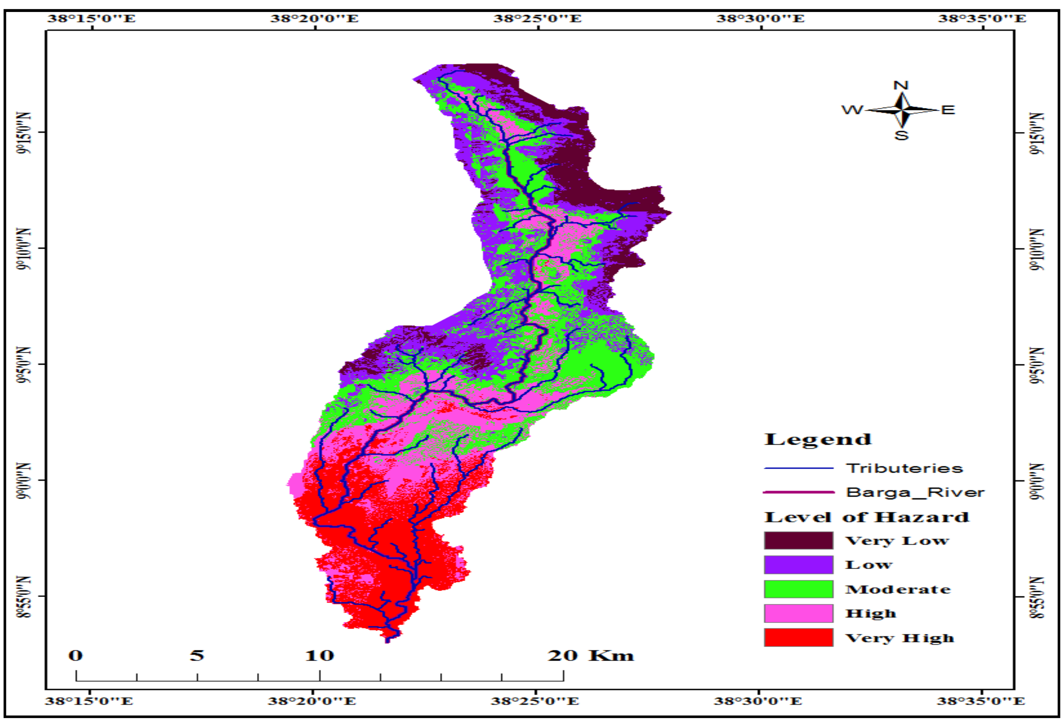


Figure: 4. 10 Flood hazard map

The lower watershed floodplains located at the confluence Awash River has highly flooded area. Flood of study area was occurs depend on different: the first when Barga River arrive at entrance of Awash the water was back rise its level, the second case area has flat slope and last case was follow the first two case and due to slope of the area was flat and at junction the velocity of water is low. Therefore sediment concentration developed was making a delta that narrows the river bank and produced a flood almost in every year during rainy season and floodwater inundation lasts four more than months' time. The summaries of flood hazard area were shown in (Table 4.13)

Table: 4. 13 Area depend level of flood hazard in hectare and percent of the area

Ranking	Area		Level of Hazard
	Ha	%	
1	3114.578	10.09459	Very Low
2	6894.188	22.34459	Low
3	8696.063	28.18461	Moderate
4	6267.109	20.31219	High
5	5882	19.06402	Very High
Total area	**30852.92**	**100**	

4.2.1 Validation of the flood hazard map

To perform the validation of the flood hazard maps results, the locations of the historical flood events were generated based on field inspection information during the field surveying of Barga watershed by researcher and providing relevant information concerning flood events. According to the comparison of ground truth data of flood hazard affected sites and flood hazard map of Barga watershed was as shown in the (Figure 4.11), the result was in agreed with the reality. The above flood hazard map of watershed verified with 14 points of flood affected areas which collected by the researcher using GPS reading ground truth data at the field surveying during September, 2019 flood. Therefore, land use planners can use this information to make environmentally sound land use decisions. Furthermore, Flood Management Units (FMU) of Ejere District and Adaa Barga district can also use this information to manage the flood problems of Barga river watershed.

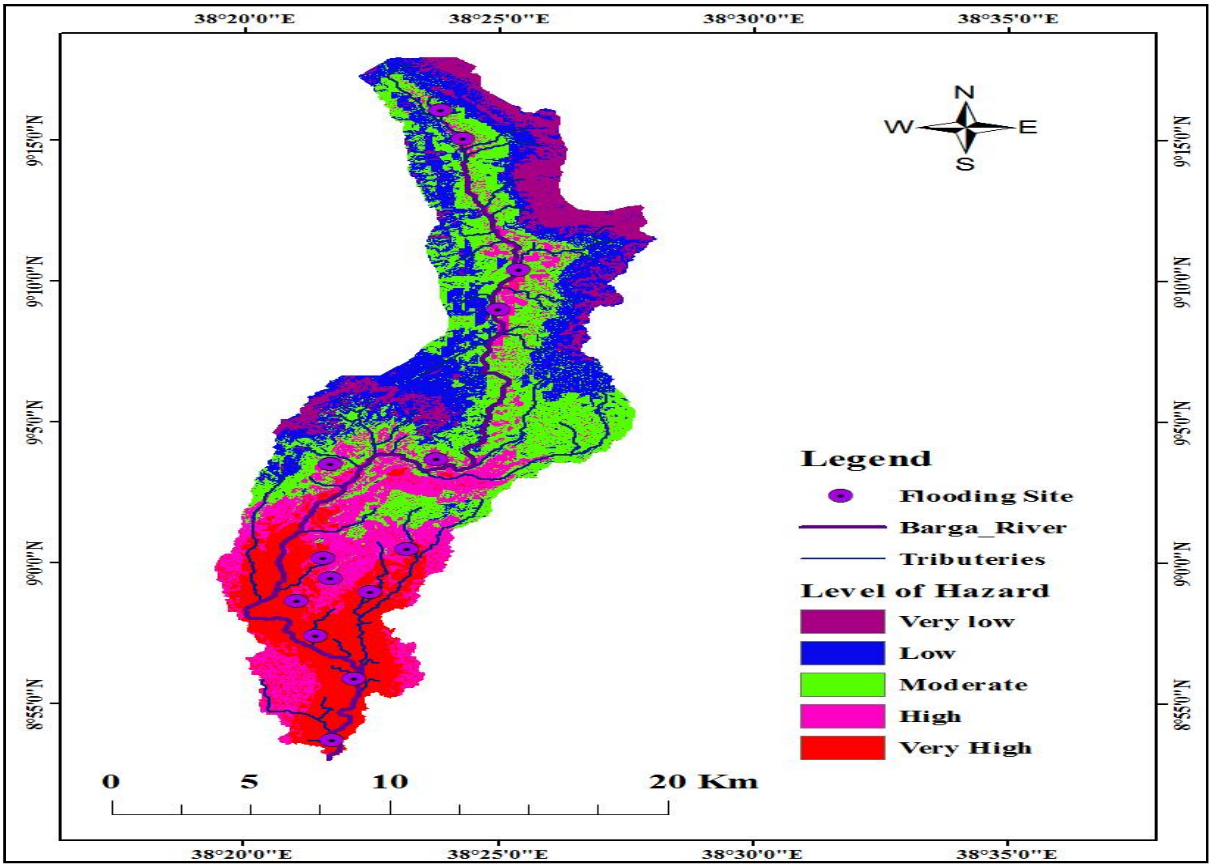


Figure: 4. 11Map of validation of flood hazard

These historical flood points location of were overlaid on the modeled output. Table (4.14) shows examples of these historical flood points, their x-y coordinates as well as the location of the respective modeled flood hazard zones. All historical flood points in (Table 4.14) are located on the high and very high flood hazard zones, according to the modeled output which indicates the reliability of the flood hazard model used in this study.

Table: 4. 14 Ground truth location of flood event in 2018 used for validation flood hazard map

Flooding site	X	Y	Location at modeled flood hazard zones
Amarro 1	38.3745	8.9832	Very high
Amarro 2	38.3868	9.0085	Very high
Arrabsa 1	38.3614	9.0586	High
Arrabsa 2	38.3962	9.0617	High
Baso 1	38.4047	9.2513	Moderate
Baso 2	38.3972	9.2682	High
Dhibu 1	38.3694	8.9319	Very high
Dhibu 2	38.3624	8.8954	Very high
Hora 1	38.3505	8.9778	Very high
Hora 2	38.3568	8.9573	Very high
Inaftu 1	38.4229	9.1737	Moderate
Inaftu 2	38.4164	9.1504	High
Kimoye 1	38.3591	9.0033	Very high
Kimoye 2	38.3615	8.9914	High

4.3 Factor development for flood risk

Flood risk is the combination of the flood hazard, vulnerability and the element at risk. The three factors, flood hazard, population density and land use of the watershed remained to be equally important in the weighted overlay process and again it was done systematically using Arc GIS model builder. The land use land cover of the watershed was reclassified based on their sensitivity to flooding. The classification of factors was discussed as below.

4.3.1 Land use factors for risk

The major land uses in Barga watershed was classified as agricultural land, settlement, grass land, shrubs land, woodland, forest land, bar land and wetland. The land use types of the sub-basin were reclassified into a common scale in order of sensitivity for the flood risk analysis. The land use was reclassified as follows: agriculture and wet land, bare land and settlement, grass land, wood and shrub land, forest land, are very high, high, moderate, low and very low respectively. Accordingly, agriculture and wet land, area were given more weight which was equal to 5, bare land and settlement weight 4, Grass land was given was given weight 3, wood and shrub land given weight of 2 and forest/dense forest was given weight 1. The reclassified land use due to the risk level was shown as (Figure 4.12)

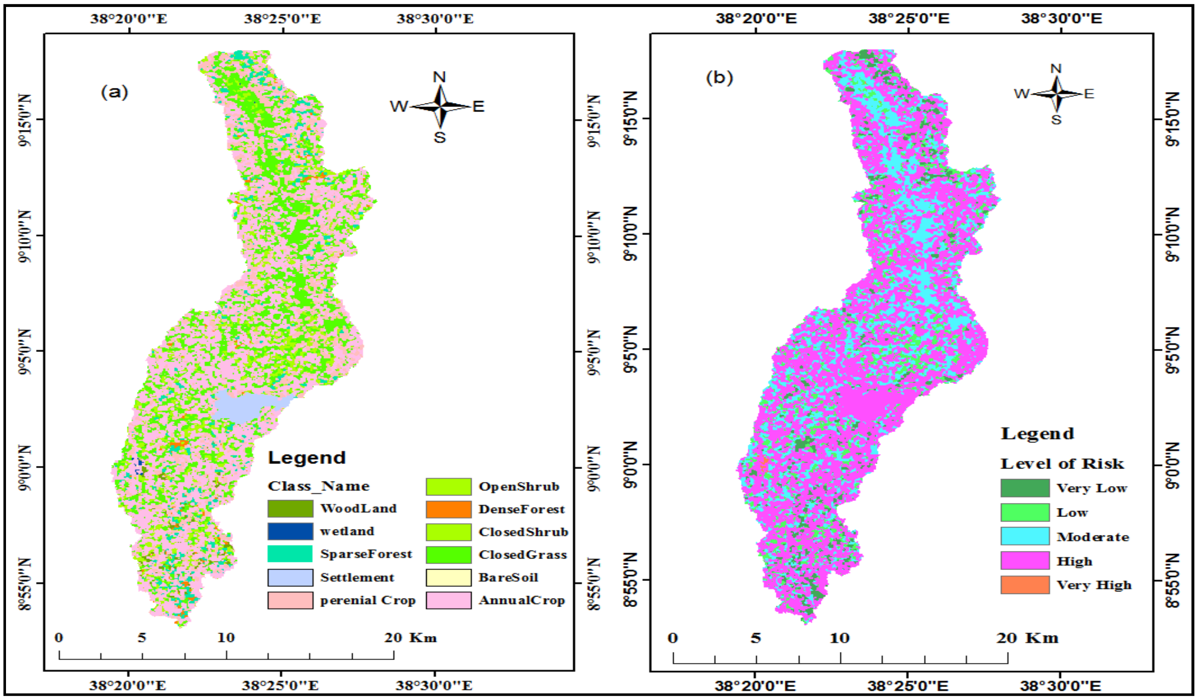


Figure: 4. 12 (a) LULC and (b) Reclassified LULC for risk map

4.3.2 Population factors

High population density is strongly affected by flood and while an area of relatively low population density is the least to be affected by flood (Bedasa, *et al.*, 2018). Gross population density calculation method is used to calculate the number of person per square kilometers. Population data is the point data which is collect from the Ejere district health center. The point data was import to Arc GIS and calculate the population density using IDW method. Then population density was reclassified into five sub-factors which are classified using equal interval method. And new values re-assigned in order of increasing number of population that is more susceptible to flood hazard. The population density was reclassified in the assumption that the denser the population, the more vulnerable it will be to flood hazard. The reclassified population of the Barga watershed was shown as (Figure 4.13)

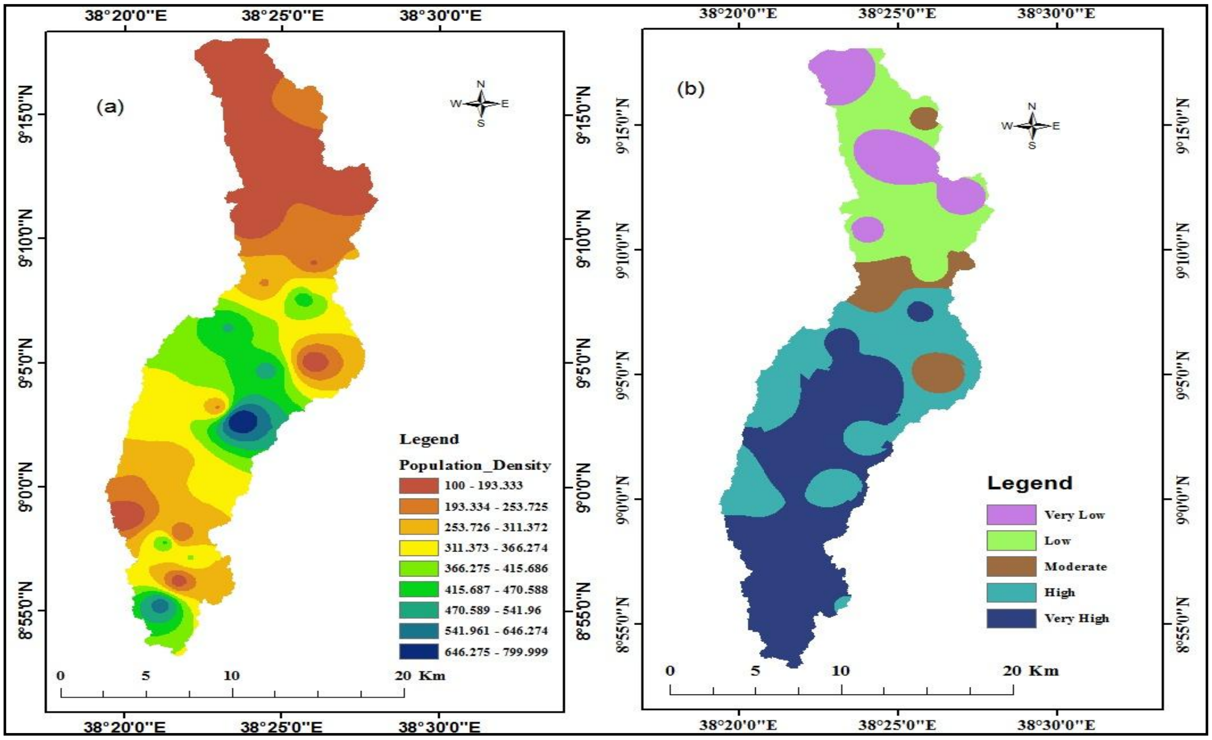


Figure: 4. 13 (a) Population density and (b) Reclassified map

The summaries of flood risk parameter were shown in the (Table 4.15) including their area weight and rank of which due to flood risk. To get the exact flooding area within historical background of the study area was evaluated many times and the last using the equal weight it overlap the exactly within flooding site of the study area.

Table: 4. 15 Summary and weight of flood risk

Factors	Weight	Sub-factors	Level of risk
Flood hazard map	0.3333	Very high	5
		High	4
		Moderate	3
		Low	2
		Very low	1
Population density (person per/Km^2)	0.3333	2,962.579 - 4,499.978	5
		1,757.120 -2,962.579	4
		936.009 -1,757.120	3
		446.836- 936.009	2
		45.017- 446.836	1
Land use types (based on their sensitivity to flooding)	0.3333	Bare land/wetland	5
		Agriculture/settlement	4
		Grass land	3
		Wood & Shrub land	2
		Forest land	1

4.4 Flood risk map

The flood risk of the Barga watershed was analyzed using (equation 3.2) by considering the two elements at risk: population density and land use land cover by assuming vulnerability and the flood hazard level. Flood risk mapping and assessment was done for Barga watershed by taking population and land use/land cover elements that are at risk combined with the degree of flood hazards of the watershed. According to the flood risk map (Figure 4.14), it was estimated that 451.9375, 3994.188, 10650.92, 11630.7, 3880.094 hectare areas of watershed were subjected respectively to very high, high, moderate, low, and very low flood risk (Table 4.14).

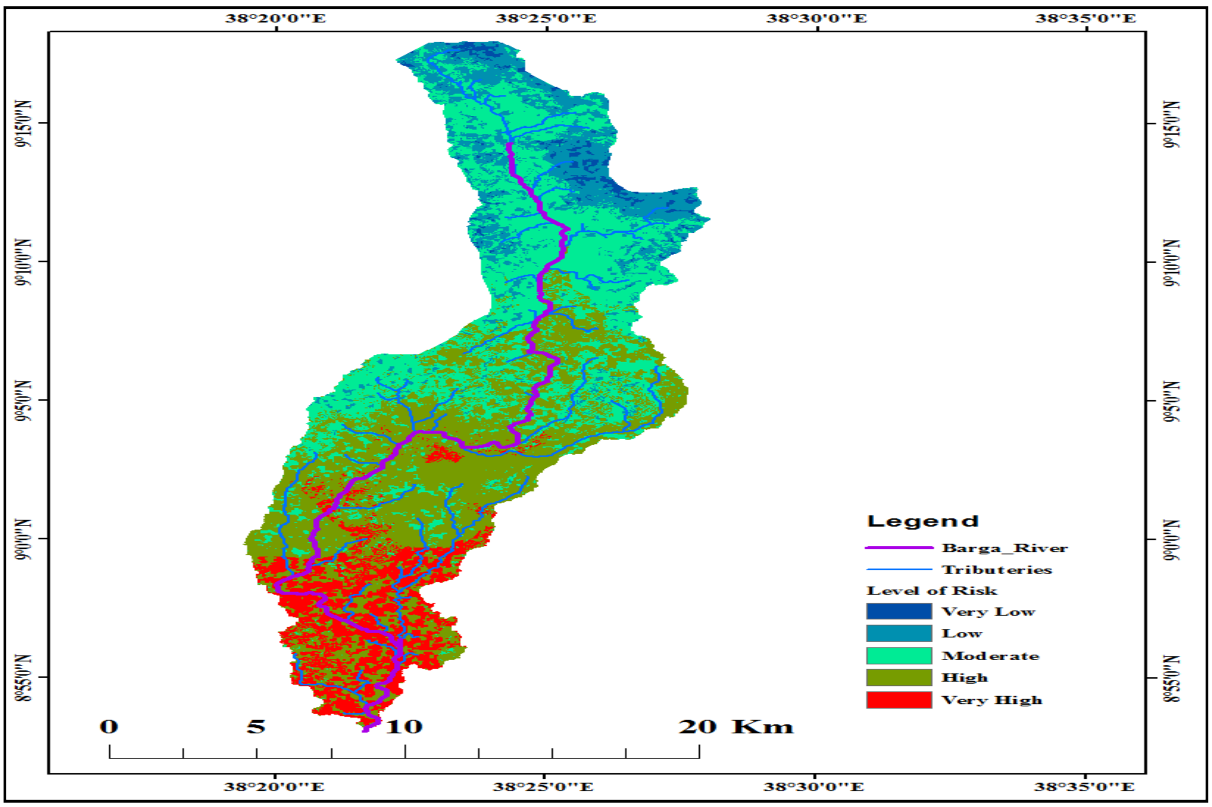


Figure: 4. 14 Flood risk map

Elements at risk considered in this study show different levels of risk. From area that are about twenty seven percent of their area under flood risk include Kimoye (63.1), Inaftu (70.3), Hora (87.5), Dibu (95.2), Amareso (75.8), Arrabsa (85.5) and Baso (55.5%) to the other element at risk, land use/land cover, 81.8% swamps, 81.6% grass lands, 92.8%agricultural lands were under high to very high flood risk.

Table: 4. 16 Flood risk area in hectare and percent of the area

Rank	Area %		Level of Risk
	Ha	%	
1	703.9375	2.281597	Very Low
2	3994.188	12.94593	Low
3	10650.92	34.52168	Moderate
4	11630.7	37.69734	High
5	3880.094	12.57613	Very High
Total area	**30852.84**	**100**	

4.4.1 Validation of flood risk map

Performance of the flood risk map of the watershed was the same ground truth point location which listed in (Table: 4. 17) and procedure of used for flood hazard map. Therefore checked flood risk map was shown as (Figure 4.15).

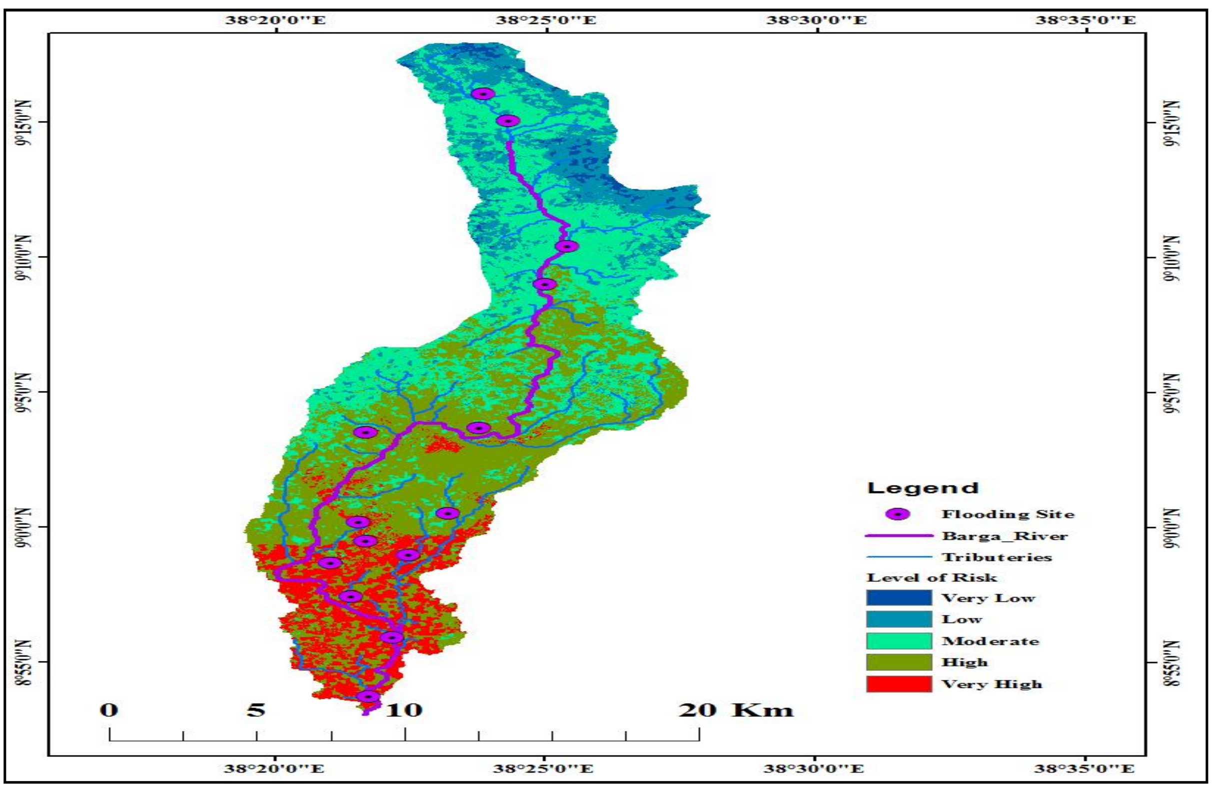


Figure: 4. 15 Map of validation of flood hazard

Table: 4. 17 Ground truth location of flood event in 2018 used for validation flood risk map

Flooding site	X	Y	Location at modeled flood risk zones
Amarro 1	38.3745	8.9832	Very high
Amarro 2	38.3868	9.0085	High
Arrabsa 1	38.3614	9.0586	Moderate
Arrabsa 2	38.3962	9.0617	High
Baso 1	38.4047	9.2513	Moderate
Baso 2	38.3972	9.2682	Low
Dhibu 1	38.3694	8.9319	Very high
Dhibu 2	38.3624	8.8954	High
Hora 1	38.3505	8.9778	Very high
Hora 2	38.35688	8.9573	High
Inaftu 1	38.42295	9.1737	High
Inaftu 2	38.4164	9.15035	High
Kimoye 1	38.3591	9.0033	High
Kimoye 2	38.3615	8.9914	High

4.5 Flood frequency

Hydrologic systemic sometimes impacted by extreme events such as difficult storms floods and droughts. The magnitude of an extreme event is inversly related to its frequency of occurrence, very extrem events occurring less frequnacy than more moderate events. According to (Chaw, *et al*., 1988) the probability occurrence of an event in any observation is the inverse of its return peroid $P(X \geq X_T) = 1/T$.

The objective of frequecy analysis of hydrologic data is relate the magnitude of extreme events to thair frequency of occurrece thruough the use of probability distributions. The hydrological data analyzed are assummed to be indepenent and identically distributed, and the hydrological system producing them (e.g. a storm rainfall system) is considered to be stochastic, space independent and time independent (chow *et. al,*. 1988) the hydrological data employed should be carefully selected so that the assumptions of independence and identical distribution are statisfied. Inpractice this is often achieved by selecting the annual maximumof the from daily variable being analysized (e.g. the maximum annual discharge which is the largest instantaneous peak flow occurring at any time during the year) with the expectation that successisve observation this variable from year to year will be independent. The result of flood frequency analysis can be used for many enginering purpose: for the design of dams, bridge, culverts, and flood control structure; to determine the economic value of flood control projects and to determine flood plain and determine the effect of encroachments on the flood plain.

The flood frequncy analysis in this study was done by using annual maximum daily transferd discharge level data at Barga outlet point that is at the confluence of Awash River. The outlet is located at 38^0.361 E longitude and 8^0.884 N latitude and has elevation 2050m msl. The calculation steps of flood based parson type 3 distribution and general logistc distribution method that is described in previusly the methology parts of the study. The best fit of the distribution of the frequency analysis for barga River is also done by L-moment dirstribition method goodness of fit.

4.4.1 Selection of best fit disribution using L-moment method

Distribution of the maixmum stream flow for flood frequency analysis was done by L-moments distribution method of selection of best fit method. From the eight distribution methd like Gambels, log person type 3, lognormal, normal ditribution, general extrem value, uniform distribution, General logistic, and exponential distribution the best fit for the Barga River outlet is person type III distribution method.The statistics of L-skewness and L-kurtosis of outlet identified outlet is shown in (Figure 4.16), along with the theoretical lines for some distributions. This also justified for outlet flood frequency analysis. Therefore, (Figure 4.16) shows that the most possible fitting distribution is person type III distribution and general logistic method.

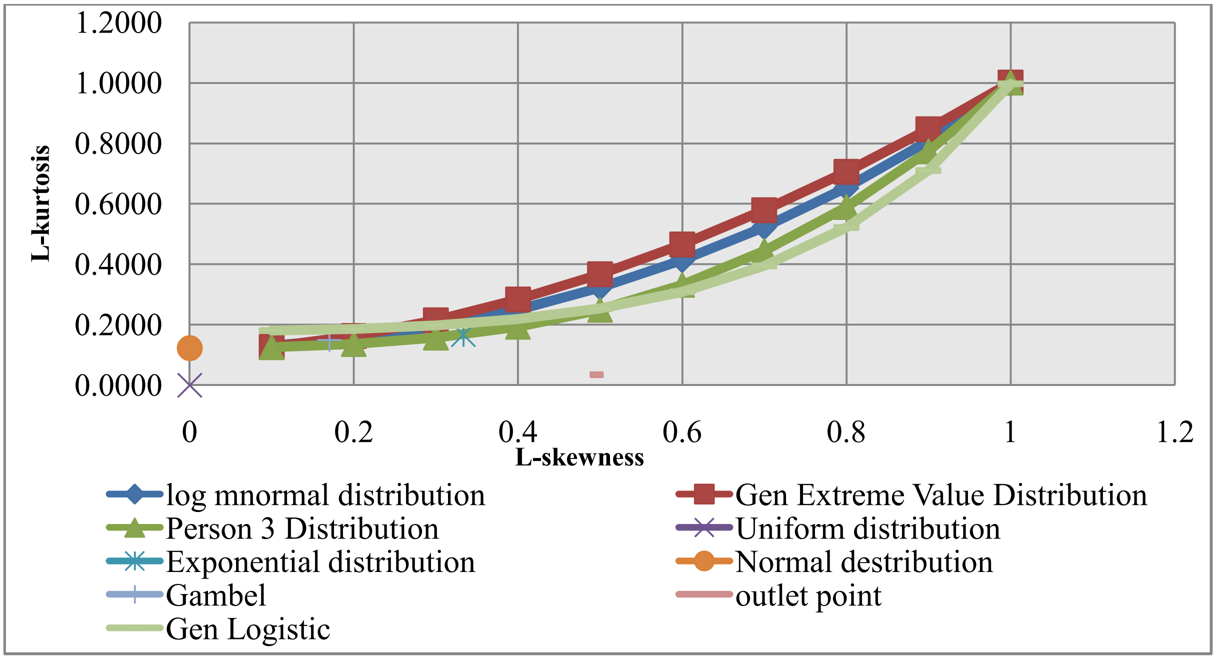


Figure: 4. 16 Outlet L-moment ratio diagram for two identified region

4.4.2 Flood frequency analysis

After selection of best-fit distribution, the desired quintile estimates are computed from the statistics of the adopted distribution. Flood estimates are sometimes requested for return period depending on their record data, up to 200 years. It may also be desired to estimate the return period of a deterministically derived probable maximum flood. The reliability of extrapolating of flood frequency curve to such return periods is generally extremely low a minor change in the data series or in the filling distribution can make huge differences to the estimates. Where such estimates are required, it is advisable to consider additional studies using methods other than standard frequency analysis (Ramachandra, *et al*., 2000). Flood frequency discharge was calculated using person type (III) distribution and general logistic method at the outlet of the Barga River for 2, 10, 15, 20, 25, 50, 100, and 200 year return period flood are shown below.

Table: 4. 18 Discharge of outlet of Barga River at time T

T	F	P	KT	Discharge (m^3/s) P (III)	Discharge (m^3/s) Gen. Logistic
2	0.500	0.500	-0.32416	161.1908	168.1908
5	0.800	0.200	0.211754	176.9713	180.9713
10	0.900	0.100	0.573839	187.6333	195.6333
15	0.933	0.067	0.780621	193.7222	201.7222
20	0.950	0.050	0.925263	197.9813	212.9813
25	0.960	0.040	1.036216	201.2484	225.2484
50	0.980	0.020	1.373588	211.1827	238.1827
100	0.990	0.010	1.699683	220.7849	249.7849
200	0.995	0.005	2.014861	230.0656	261.0656

The flood frequency of the study area at the outlet was calculated by two methods. When compare the value of discharge of the river at return period the value of discharge calculated by general logistic method is greater than the discharge which is calculated by the personal type III method. Therefore, the discharge that gets from both graphically the return period is shown by (Figure 4.17).

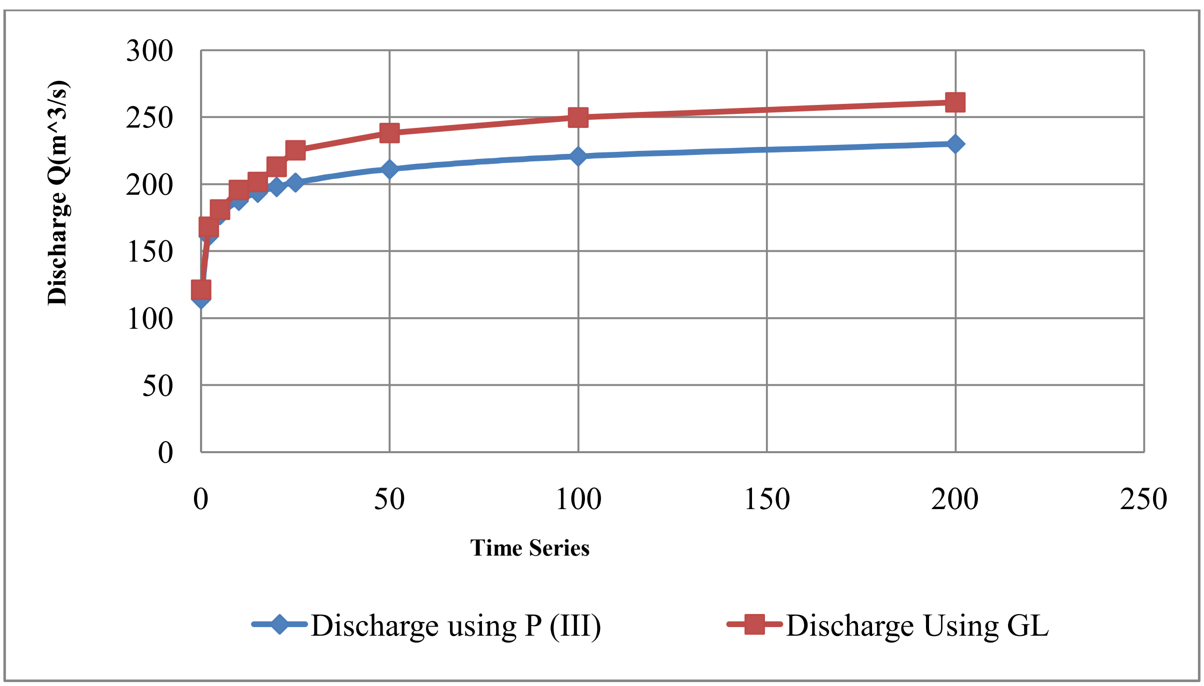


Figure: 4. 17 Graphical representation the calculated peak discharge return period

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The basic idea of flood hazard and risk assessment mapping as undertaken in this study is to control land use by flood plain zoning in order to restrict the damages. Flood hazard based methodology by means of weighted linear combination and multi-criteria analysis and considering nine (9) parameters, namely, flow accumulation, rainfall, geology, soil type, land use land cover, slope, elevation, drainage density and topographic wetness index. The relative weight of each parameter was calculated by Analytical Hierarchy Process using IDRISI software. Combination of each parameter was by GIS techniques. Considering that Slope, elevation, soil type, and drainage density as well had the highest impact on flood occurrences, especially, within the flat at the lower of Barga river watershed. The superimposition of each parameter resulted in mapping the area's flood hazard divided into five classes, from "Very Low" to "Very High" from this area. Generally flood hazard map 10.09459%, 22.34459%, 28.18461%, 20.31219%, 19.06402% of the study area was subjected to very low; low, moderate, high and very high flood hazards severity classes, respectively. The risk map of watershed was combined two elements like land use land cover, the population and hazard map. From area that are about twenty seven percent of their area under flood risk include Kimoye (63.1), Inaftu (70.3), Hora (87.5), Dibu (95.2), Amareso (75.8), Arrabsa (85.5) and Baso (55.5%) to the other element at risk, land use/land cover, 81.8% swamps, 81.6% grass lands, 92.8%agricultural lands were under high to very high flood risk. Then after, the modeled output of floods hazard and risk map, was validation map, the obtained results were validated within historical floods data obtained from field surveying of the Barga watershed Flood frequency analysis of peak hydrological data yielded the return periods of each major peak discharges and the magnitude and probability of occurrence of flood peaks of specified return periods so as to help preparedness to cope with such peaks. Finally flood frequency discharge was calculated using person type (III) distribution and general logistic method at the outlet of the Barga River for 2, 10, 15, 20, 25, 50, 100, and 200 year return period flood.

5.2 Recommendation

This investigation provides information on flood hazard and flood risk at a watershed level that could be used by the pertinent decision makers to act upon the current land use policy for reducing vulnerability to flood disaster in Barga watershed in particular. The Barga watershed blessed with ample land resources, which is one of the most agricultural development areas in Oromiya, but its proper agricultural development has been hindered by inundation, floods and poor drainage condition. Thus the responsible bodies of the Ejere and Ada'a district as well as the Oromiya Region should incorporate the flood hazard and flood risk assessment studies in their development strategies. Watershed management practices in the upper of the watershed are crucial in alleviating future flood disasters in the study area. Land use planning can play very important role to reduce the adverse effects of flooding. It is recommended to adopt an appropriate land use planning in flood prone area. Creating awareness among the society concerning optimum use of natural resources, conservation systems and their benefits by concerned bodies and nongovernmental organization (NGO) could play significant role in minimizing of environmental risk zone. In addition, since most important factor for the land cover change in the Oromiya, particularly in the study area is the increase in population, continuing the current efforts of introducing family planning to make the people aware of consequences of population pressure should be carried out intensively. Disaster related research activities should be undertaken. Application of advance techniques in soil physics, geotechnical engineering, GIS and remote sensing for flood risk assessment and risk reduction are also needed.

REFERENCES

Ali , G. M., Getinet , . T. . M. & Birke, H. . P., 2018. Flood Hazard and Risk Assessment in Robe Watershed Using GIS and Remote Sensing, North Shewa Zone, Amhara Region In Ethiopia. *IOSR Journal Of Humanities And Social Science (IOSR-JHSS),* Volume 23, PP 34-44.

Dessie, T., Ebrahim, . E. & Assayew, . N., 2018. Flood Hazard Assessment Using Multi-criteria Evaluation Approach in Dembiya Woreda, Amhara Region, Ethiopia.

Abebe, F. C., 2007. FLOOD HAZARD ASSESSMENT USING GIS IN BACHO PLAIN.

Ajin, R., Krishnamurthy, R. R., Jayaprakash, M. & Vinod, P., 2013. .Flood hazard assessment of Vamanapuram River Basin, Kerala, India: An approach using Remote Sensing & GIS techniques

Alexander, D., 1993. Natural Disasters. London.

Anon., 2018. Flood Risk Assessment in Ethiopia. *Civil and Environmental Research Vol.10, No.1*

Aris MM, 2003. GIS modeling for river and tidal flood hazard in water front city : case of study of sumuragnu. *Java indonsia. ITC, netherland,* pp. 1-12.

Aronoff, 1995. Geographic Information Systems: A Management Perspective.

asf.alaska.edu, n.d. *https:.* [Online]
[Accessed 30 8 2019].

Bedasa, . A. & Wondwossen, . M., 2018. Geospatial Based Flood Risk Assessment: The Case of Kewet District, Amhara Region, Ethiopia. *American Journal of Geographic Information System,*

Bernstein, P. L., 2011. Capital ideas evolving. John Wiley & Sons..

Calder, I. R., 1999. The Blue Revolution, Land Us Integrated Water Resources Management..

Chaw, V. T., David R., M. & Larry W., M., 1988. *AppLIED HYDROLOGY..*

CSA, 2014. Summary and Statistical Report of the Population and Housing Census..

Dagnachew, . L., Vallet-Coulomb, . C. & Gasse, F., 2003. Hydrological response of a catchment and land use change in tropical Africa: Case study south central Ethiopia.. pp. 67-85..

Daniel, M., 2010. Geology of Debre Birhan Area. Volume (NC 37-11).

Daniel, M., 2010. *Geology of Debre Birhan Area (NC 37-11),* Addis Ababa.: Geologiacal survey of Ethiopia.

Dilley, C. R. D. U., 2005. Natural disaster and hotspots: global risk analysis.. *Internaton bank for reconstructio and development/ The world bank in colubia University Woshington.*

DPPA, 2006. Joint Government and Humanitarian Partners: Flash appeal for the flood.

Emmanuel, U. A., Ojinnaka, O. C. & Baywood ., C. .., 2018. Application of Geospatial Techniques for Analysis of River Inundation and Flood Risk Potential along Lower Niger Basin in Nigeria.

FAO, 2001. Guidelines for soil description. 4th editions, FAO, Rome Federal Disaster Prevention and Preparedness Agency (FDPPA), (2006).. *Joint Government and Humanitarian Partners Flash Appeal for Flood Disaster in Ethiopia. Addis Ababa, Ethiopia..*

FDPPA, 2007. *Joint Government and Humanitarian Partners Flash Appeal for Flood Disaster in Ethiopia.,* Addis Ababa, Ethiopia.: .

Flood Alert #4, 2018. *Federal Democratic Republic of Ethiopia National Disaster,* Addis Ababa: Early Warning and.

Getahun, . Y. & Gebre, . S., 2015. Flood Hazard Assessment and Mapping of Flood Inundation Area of the Awash River Basin in Ethiopia using GIS and HEC-GeoRAS/HEC-RAS Model. *J Civil Environ Eng,*Volume 5

Hassan, A., Norio, T. & Nobuyuki, T., 2009. Distributed water balance with river dynamic-diffusive flow routing model.. Volume B, 21(4), pp. 564-572.

https://campaignforaccuracyinpublichealthresearch.com/risk-vs-hazard/, 2019. *google.* [Online]
[Accessed 03 06 2019].

https://en.m.wikipedia.org/1/2019, n.d. [Online]
[Accessed 1 12 2019].

https://en.wikipedia.org/, 2019. *google.* [Online].

International Strategy for Disaster Reduction, 2004. *Living With Risk a Global,*

JD' Fenton DipCE, B. M. P. 2018. Estimating discharge at an ungauged site.

Joint, G., 2018. *Humanitarian Partners National Flood Contingency Plan,* Addis Ababa:

Jonkman, S., 2005. Global perspectives on loss of human life caused by floods. *Natural Hazards*

Kebede, B., 2012. Application of GIS and Remote Sensing Techniques for Flood Hazard and Risk Assessment: The Case of Dugeda Bora Woreda of Oromiya Regional State, Ethiopia.. *Lecturer at Ethiopian Civil Service University. Addis Ababa, Ethiopia. Paper for the 2012 Berlin Conference on the Human Dimensions of Global Environmental Change,* pp. 1-17.

Ken, G., 2002. Community Risk Assessment in Mackay: A Multi-Hazard Risk Assessment..

Kon, W., 2002. Flood risk = hazard x exposure x vurnalibility brnail bilitry. *Flood.*

Lappas, l. & Kallioras, A., 2019. Flood Susceptibility Assessment through GIS-Based Multi-Criteria Approach and Analytical Hierarchy Process (AHP) in a River Basin in Central Greece. 06(03).

Lillesand, . M., Thomas & W. Ralph, . K., 2004. Remote Sensing and image Interpretation:.

Malczewski, J., 1996. GIS and multi-criteria decision analysis..

Margareta, W. & Debarati, G.-S., 2015. The Human Cost of Weather-Related Disasters 1995-2015.

Nelson, S., 2007. Flood Hazards, Prediction and Human Interventions.. *Tulane University. Intute: Science, Engineering and Technology.*

Nerantzis, K., Ioannis, K. & Thomas, P., 2015. Assessment of fl ood hazard areas at a regional scale using an index-based approach and Analytical Hierarchy Process: Application in Rhodope – Evros region, Greece.

Nicholls, N. .., 2001. Natural Hazards,. pp. 23: 137-155.

Ramachandra, R. & Khaled H., H., 2000. Parameter and Quantile Estimation. In: W.F.CHEN, ed. *Flood frequncy analysis.* Washington D.C: London New York Washington D.C CRC press.

Sanya, l. J. L., 2005. Remote sensing and GIS based flood vurnelability assessment of human settlements: a case study of gangentic wets bengal India. *Hydrol process.*

Seleshi, B. A. & Habil, H. H., 2000. Investigation of water Resources Aimed at Multi-Objective Development with Respect to Limited Data Situation The Case of AbayaChamo Basin. Volume 17.

Strahler , A., 1999. Strahler, A.N., (1999). Quantitative Geomorphology of Drainage basins and Channel network.. In: *In Handbook ofApplied Hydrology.* New York, NY, USA: s.n.

Susan, L., Cutter, ,. J. T. & Mitchael S., S., 1997. Handbook for Conducting a GIS Based Hazards Assessment at the County Level.. *University of South Carolina U. S.A.*

Tesfay, H. A., 2018. Flood Risk Assessment in Ethiopia. *Civil and Environmental Research Vol.10,*

UNEP, 2002. *Early Warning, Forecasting and Operational Flood Risk, Monitoring in Asia (Bangladesh, China and India), aTechnical Report of Project, Kenya,,* Nairobi. UN-Habitat, 2010.Climate Change and Sustainable Development.

Vincent, 1997. Fundamental of Geological Environmental Remote Sensing Prentice-Hall, Flood Hazard Assessment and Mapping of Flood Inundation Area of the Awash River Basin in Ethiopia using GIS and HEC-GeoRAS/HEC-RAS Model.. *Eglewood Cliffs NJ. J Civil Environ Eng 5: 179.*

WFP, 2014. *Extensive floding in Ethiopia: World Food Program (WFP)*

Woubet, G. & Dagnachew, L., 2014. Flood Hazard and Risk Assessment Using GIS and Remote sensing In Fogera Wareda Northwest Ethiopia.

Yirga, K. W., 2016. Flood Hazard and Risk Assessment Using GIS and Remote Sensing in Lower Awash Sub-basin, Ethiopia. Volume 6.

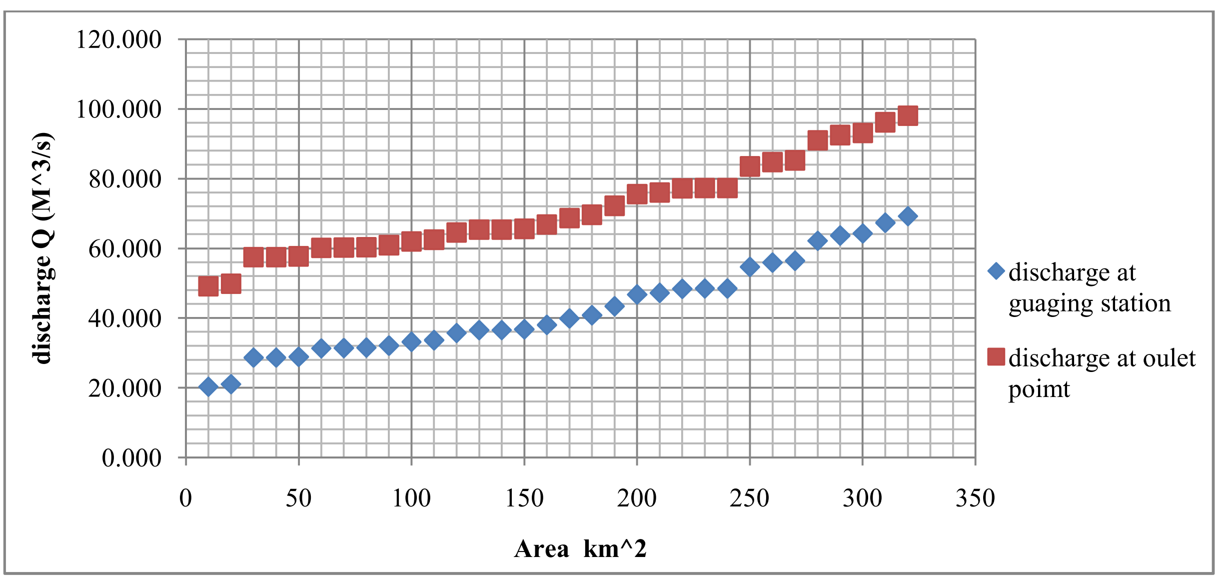
Yonas, T. A., 2015. Flash Flood Hazard in Dire Dawa, Ethiopia Vol. 1, No. 4. *Journal of Social Sciences and Humanities,* pp. pp. 400-414.

Appendix

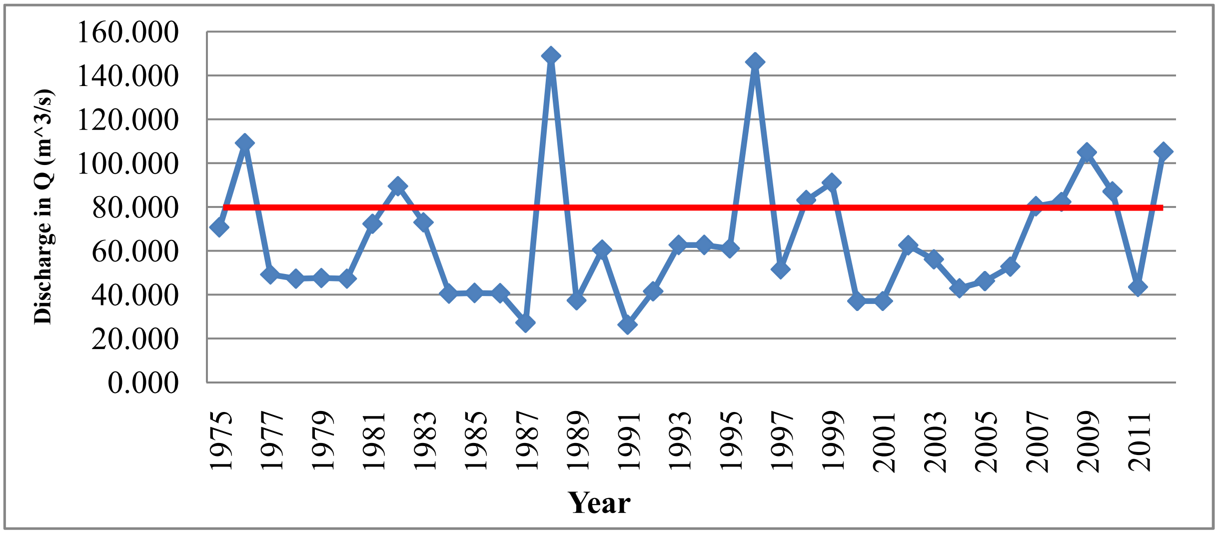
Barga river discharge at gauge station and outlet

year	Q gauge station	Q outlet	year	Q gauge station	Q outlet
1975	54.672	70.63837	1994	48.482	62.64063
1976	84.424	109.0791	1995	47.219	61.00879
1977	38.029	49.13495	1996	113.038	146.0495
1978	36.538	47.20852	1997	39.861	51.50197
1979	36.753	47.48631	1998	64.274	83.04451
1980	36.538	47.20852	1999	70.419	90.98409
1981	55.921	72.25211	2000	28.634	36.99624
1982	69.213	89.4259	2001	28.634	36.99624
1983	**56.417**	72.89313	2002	48.363	62.48688
1984	31.281	40.41627	2003	**43.379**	56.04752
1985	**31.509**	40.7103	2004	33.167	42.85306
1986	31.395	40.56356	2005	35.723	46.15551
1987	20.997	27.12894	2006	40.813	52.73199
1988	115.168	148.8015	2007	62.144	80.29247
1989	28.865	37.29471	2008	63.665	82.25766
1990	46.758	60.41316	2009	81.134	104.8283
1991	20.294	26.22064	2010	67.341	87.0072
1992	32.079	41.44732	2011	33.648	43.47453
1993	48.482	62.64063	2012	81.388	105.1565

Cooperation of the discharge at stream gauge and at outlet point



The discharge if Barga river after transferred from gauge station to outlet point



Ms Excel calculation of L-moment parameters

Year	max	rank	b1	b2	b3
			(n-y)x/(n(n-1)	(n-Y)(n-Y-1)X/(n(n-1)(n-2))	(n-Y)(n-Y-1)(n-Y-2)X/(n(n-1)(n-2)(n-3))
1988	148.8015	1	3.9158	3.9158	3.9158
1996	146.0495	2	3.7395	3.6357	3.5318
1976	109.0791	3	2.7153	2.5645	2.4179
2012	105.1565	4	2.5429	2.3310	2.1312
2009	104.8283	5	2.4604	2.1870	1.9371
1999	90.98409	6	2.0708	1.7832	1.5284
1982	89.4259	7	1.9717	1.6431	1.3614
2010	87.0072	8	1.8565	1.4955	1.1964
1998	83.04451	9	1.7129	1.3322	1.0277
2008	82.25766	10	1.6381	1.2286	0.9127
2007	80.29247	11	1.5419	1.1136	0.7954
1983	72.89313	12	1.3480	0.9361	0.6419
1981	72.25211	13	1.2847	0.8565	0.5628
1975	70.63837	14	1.2058	0.7704	0.4842
1993, 1994	62.64063	15	1.0247	0.6262	0.3757
2002	62.48688	17	0.9333	0.5185	0.2815
1995	61.00879	18	0.8678	0.4580	0.2356
1990	60.41316	19	0.8164	0.4082	0.1983
2003	56.04752	20	0.7175	0.3388	0.1549
2006	52.73199	21	0.6376	0.2834	0.1214
1997	51.50197	22	0.5861	0.2442	0.0977
1977	49.13495	23	0.5242	0.2039	0.0757

1979	47.48631	24	0.4728	0.1707	0.0585
1980	47.20852	25	0.4365	0.1455	0.0457
1978	47.20852	26	0.4029	0.1231	0.0352
2005	46.15551	27	0.3611	0.1003	0.0258
2011	43.47453	26	0.3710	0.1134	0.0324
2004	42.85306	29	0.2743	0.0610	0.0122
1992	41.44732	30	0.2358	0.0459	0.0079
1985	40.7103	31	0.2027	0.0338	0.0048
1986	40.56356	32	0.1731	0.0240	0.0027
1984	40.41627	33	0.1437	0.0160	0.0014
1989	37.29471	34	0.1061	0.0088	0.0005
2000, 2001	36.99624	35	0.0789	0.0044	0.0001
1987	27.12894	37	0.0193	0.0000	0.0000
1991	26.22064	38	0.0000	0.0000	0.0000
Sum	**2363.8407**		**39.3903**	**29.7211**	**24.2128**
Mean	**64.8284**				

Z – Value of each probability distribution

Assumed z3	Log-normal distribution	General Extreme value distribution	Pearson distribution	Gen logistic	Uniform distribution	Exponential distribution
0.1	0.1306	0.1265	0.1255	0.1750	(0,0)	1/2, 1/3
0.2	0.1540	0.1626	0.1359	0.2000	Normal distribution	
0.3	0.1935	0.2149	0.1569	0.2417	0,0.1226	
0.4	0.2495	0.2829	0.1929	0.3000	Gumbel distribution	
0.5	0.3226	0.3664	0.2493	0.3750	0.1699, 0.1504	
0.6	0.4133	0.4649	0.3314	0.4667	Outlet point	
0.7	0.5226	0.5781	0.4435	0.5750	0.4874,0.0705	
0.8	0.6526	0.7054	0.5894	0.7000		
0.9	0.8077	0.8465	0.7729	0.8417		
1	0.9981	1.0008	1.0006	1.0000		

Average yearly rainfall at five stations

year	Aruse	Enselale	kimoye	Adis alem	Olnkomi
1991	647.97	647.972	274.2	238.100	647.972
1992	637.80	637.801	225.8	176.000	637.801
1993	650.34	650.342	237.4	173.900	650.342
1994	636.77	636.768	219.7	359.800	636.768
1995	572.13	572.125	254.8	262.700	572.125
1996	671.12	671.118	297.9	224.000	671.118
1997	673.59	673.59	248.1	243.100	673.59
1998	751.93	751.931	263.4	289.500	751.931
1999	722.11	722.111	211.3	262.200	722.111
2000	666.92	666.922	223	266.600	666.922
2001	656.53	656.53	247.8	309.700	656.53
2002	502.14	502.139	198	333.100	502.139
2003	657.97	657.97	184.1	232.100	657.97
2004	638.80	638.8	261.2	212.500	638.8
2005	706.11	706.108	176.9	224.000	706.108
2006	493.98	493.983	241.1	334.300	493.983
2007	531.93	531.93	246.7	237.300	531.93
2008	540.24	540.238	234.5	291.500	540.238
2009	628.34	628.337	289.7	318.300	628.337
2010	791.91	791.912	300	340.100	791.912
2011	370.23	370.231	259.6	312.400	370.231
2012	442.98	442.982	244.1	318.800	442.982
2013	508.23	508.23	300.6	317.400	508.23
2014	587.34	587.339	229.8	238.100	587.339
2015	494.38	494.38	167.5	176.000	494.38
2016	526.35	526.354	205.9	173.900	526.354
2017	537.29	537.293	241.2	359.800	537.293
2018	619.41	619.408	292.4	262.700	619.408

Checked the consistence of data three station double mass curve