

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Civil and Architecture Engineering

Department Of Geodesy and Geomatics Engineering

MSC in Geodesy and Geomatics Engineering

GIS Based Flood Hazard and Risk Assessment: A Case of Sibu

Sire Woreda Oromia Region, Ethiopia

A Thesis Submitted to School of graduated studies of Adama Science and Technology University in Partial fulfillment of the requirements for the award of the degree of Masters Science in Geodesy and Geomatics Engineering

By

Dereje Sufa Kenea

May, 2017

Adama, Ethiopia

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Adama, Ethiopia

CANDIDATE’S DECLARATION

I the under signed, declare that the thesis entitled “***GIS Based Flood Hazard and Risk Assessment: A Case of Sibu Sire Woreda, Oromia Region, Ethiopia***” has been carried out by me under the supervision of Dr. Tilahun Erduno and Mr. Daniel Alemayehu, Department of Geodesy and Geomatics Engineering, Adama Science and Technology University, Adama during the year 2016-2016/17 as a part of Master of Science program in Geodesy and Geomatics Engineering.

I further declare that this work has not been submitted to any other University or Academic institution for the award of any degree or diploma and that all sources of material used for the thesis have been duly acknowledged.

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CERTIFICATE

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ABSTRACT

Floods are probably the most recurring, widespread, disastrous and frequent natural hazards of the world. However, human activities in many circumstances change flood behavior. Activities in the flooded area such as land clearing for agriculture may increase the magnitude of flood which increases the damage to the properties and life.

Sibu Sire Woreda is one of the most severely flood affected areas in Oromia region in general and Indris Catchment in particular. The Woreda is situated in the downstream part of Indris, Jalale and Gewiso rivers. Due to the rapid increase of population in this area, people are exploiting natural vegetation and extending cultivation, which have led to land degradation and vulnerable to flood hazard. Hence, in order to manage such problem, a complete understanding of hazard identification and risk analysis is very crucial.

Therefore, the present study was carried out to assess the flood risk in Sibu Sire Woreda with the application of Multi Criteria Evaluation (MCE) technique in GIS environment. To do this causative factor rainfall, drainage density, Slope, elevation, soil type, geology, were developed in the GIS and land use land cover Remote Sensing environment using Erdas Imagine software. Then, weighted overlay analysis in multi criteria evaluation (MCE) technique was used in order to arrive at flood hazard map depending on the (AHP) pair wise comparison of eigen vector value and the weighted overlay of flood hazard map Sibu Sire Woreda, population density, vulnerability(land use land cover) give flood risk map of the study area.

The findings of the study revealed that 22.42% of the Woreda is under high to very high flood risk. Thus, the study will help the concerned authorities to formulate their development strategies according to the available flood risk to the area. The existing KAP study is very necessary to raise the awareness level of the society. To conduct the analysis the SPSS software technique was important using the KAP data collected through the semi-structured method. Hence, this study was conduct to high up the awareness level of the society to any disaster and plan good strategies to the available disaster Preparedness.

Key words: *Flood, Hazard, Risk, GIS, Remote Sensing, MCE, Sibu Sire Woreda, SPSS, KAP.*

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LIST OF ACRNOMYS

AHP	Analytical Hierarchy Process
CSA	Central Statistics Agency
DEM	Digital Elevation Model
DPPA	Disaster Preparedness and Prevention Agency
ETM	Enhanced Thematic Mapper
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental System Research Institute
FDRE	Federal Democratic Republic of Ethiopia
GPS	Global Positioning System
LULC	Land Use / Land Cover
MCE	Multi Criteria Evaluation
NGO	Non-Governmental Organization
NMA	National Meteorological Agency
SNNPR	Southern Nations Nationalities and Peoples Region
TIN	Triangulated Irregular Network
UNOCHA	United Nation Office for the Coordination of Humanitarian Affairs
USGS	United State Geological Survey
UTM	Universal Transverse Mercator
WLC	Weighted Linear Combination
WMO	World Metrological Organization
KAP	Knowledge, Attitude, Practice (Action)
SPSS	Statistical package for the Social Sciences

1. INTRODUCTION

1.1. Background of the Study

Flooding is a natural process that will remain a major hazard as long as people live and work in flood prone areas. Floods normally occur when the streams or rivers flow out of their confines. Similarly, river flooding is also 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. Floods vary considerably in size and duration. Flood can be defined as any relatively high water flow that overtops the natural or artificial banks in any portion of a river or stream. Flooding is the most common environmental hazard due to the widespread geographical distribution of river valleys and coastal areas. By attraction of human beings to such areas for settlements and farming make it as a fatal obstacle to social progress both in developing and developed countries (Jayaseelan, 2001) .

Flooding causes billions of dollars' worth damage of properties and thousands of deaths and injuries each year worldwide (Keith Smith and Roy Ward, 1998). Asia is one of the most flood affected (prone) continents in the world where high percentage of damage to property and loss of life is registered every year.

According to (DPPA, 2006) topographically, Ethiopia is both a highland and lowland country. It is composed of nine major river basins, the drainage systems of which originate from the centrally situated highlands and make their way down to the peripheral or outlying lowlands. The country experiences two types of floods: *flash* 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. 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. 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. The flood that has recently assaulted Southern Omo Zone and South Gondar (mainly Fogera Woreda) Zone is a typical

manifestation of river floods. Therefore, owing to its topographic and altitudinal characteristics, flooding, as a natural phenomenon, is not new to Ethiopia. They have been occurring at different places and times with varying magnitude.

Some parts of the country do face major flooding. Most prominent ones include: extensive plain fields surrounding Lake Tana and Gumara and Rib Rivers in Amhara Regional State; areas in Oromia and Afar Regional States that constitute the mid and downstream plains of the Awash River; places in Somali Regional State that fall mainly along downstream of the Wabishebele, Genalle and Dawa Rivers; low-lying areas falling along Baro, Gilo and Akobo Rivers in Gambella Regional State; downstream areas of Omo River in the Southern Nations, Nationalities and Peoples Regional State (DPPA, 2006). Due to the rapid increase of population in Sibu Sire Woreda, people are exploiting natural vegetation and extending cultivation, which have led to land degradation and deterioration of the ecosystem. As a result, the area has become susceptible to erosion and flood events. The Woreda has diverse topography ranging from very flat to mountainous. Such relief types are fairly distributed, while the flat to undulating plain part of the area in Woreda takes about 40 % of all areas. Such a topographic setup is believed to have been generating heavy flooding at the low. Most rivers as well as their numerous tributaries in the Sibu Sire Woreda initiate their courses from relatively higher elevations and the immediate Catchment areas are poorly covered exposing the flat areas to heavy flood during the rainy season.

Although flooding cannot be wholly prevented, its impacts can be reduced through appropriate planning and management. Damaging effects of flood disaster on lives and property can be reduced by structural dams and non-structural (legal instruments, public awareness, forecasting and early warning systems and rescue operations) measures.

Hence, the agricultural and other development activities carried in the area requires flood protection measures. Therefore, to reduce the flood impacts on economic and human settlements, flood hazard and risk mapping needed and analysis of the existing awareness level of society about the flood disaster. Geographical Information Systems (GIS) is one of the techniques that can be used flood level forecasting and management in order to assist in the reduction of human and economic losses through the delineation of the areas at risk of being flooded. This was in mind; this study was conducted to analysis the flood risk of Sibu Sire

Woreda by using multi-criteria evaluation technique in Geographical Information Systems (GIS) environment. SPSS software is very important to analysis the existing KAP study of the society and used to increase the awareness level society.

1.2. Statements of Problem

There was information gap related to flooding in the Study area due to the knowledge about the cause of flood event such as, afforestation, overgrazing, sand sedimentation, soil erosion, land degradation and flood protection of the area and human settlement or location planning strategy. Flooding and poor drainage conditions are major environmental problems known to the Indris catchment. High flood which is due to the intensive rainfall over the area, low drainage density, gradually decreasing slope towards the River course, and poor drainage systems are major threats to the localities living within the affected area and surroundings (Woreda Agricultural and Rural Development , 2013).

According to the (Woreda Natural disaster protection and agricultural office ,2013), in the study area 15% hectare of the agriculture annually affected and 19 farmers were displaced from their home in August,2013. Recently for nearly the whole month of August, 2013 a major flood swept through Jarso Wama kebeles and all surrounding peasant areas, resulted in the loss of life, property, structural facilities, housing and livelihoods. Although the most severe flood occurred at some intervals, floods and inundation of known areas in the Woreda were happens every year causing loss of animal life, damage to property and infrastructures.

This condition directs towards post flooding event action oriented strategy without good prior knowledge on flood hazard and risk zonation. Some kebeles are located on the lower topographic position in Sibu Sire Woreda are annually inundated especially during the period from July to September. Considerable number of farmers in the study area have got plots located in the inundation area. Their farming is constrained by the risks of crop losses by floods that occurs several times every rainy season.

This has aggravated the flood hazard disaster in the rainy seasons. The sociological damages caused by inundation are also serious. Some settlements are often isolated during the rainy season due to flood and inundation and the life is completely disrupted. This is witnessed on the last flood hazard disaster for instance agricultural land was also damaged.

1.3. Objectives of the Study

The **general objective** of this study is to assess the flood hazard and risk in Sibu Sire Woreda using Arc-GIS technique. In connection with the above general objective the following **specific objectives** are outlined to:

- Identify and develop factors relevant for flood hazard and risk analysis.
- Analyze flood hazard, vulnerability and risk in Arc-GIS environment for study area.
- Evaluate the awareness of flood hazard, vulnerability and risk on livelihoods of the people in study area
- Recommend some mitigation measures for the recurrent flood risks.

1.4. Research Questions

The study is aimed to answer the following leading questions:

- How the flood hazard and risk study is conducted?
- What is the level of flood hazard, vulnerability and risk in study area?
- What is the level of awareness of society living in the Sibu Sire Woreda?

1.5. Significance of the Study

The Sibu Sire Woreda agricultural and rural development office can be foremost beneficiary of this study, because they use the outcome of this study it for creates public awareness rising on land users particularly farmers, Flood Risk Management Strategy and planning (prevention, mitigation), soil contamination problem after flood for crop production, flood preparation (flood detection, forecasting, emergency planning), flood incident management and response (flood warning, actions of emergency services disaster protection office, healthcare providers). In addition the Sire town municipality is used for land use planning, environmental planning, land management, strategically urban expansion, construction of public service (such as, sport field, school, road,) and recommend policy makers and concerning government agents. It also generates useful information for environmental and education planners, environmental resource protection organizations. It also helps to have a better understanding of related training required for farmers in the area. Again the non-governmental organization (NGO), insurance sectors are used this study to help the people livelihoods located in flood risk area.

In addition it will use as stepping stone for any person who interested to conduct research on related topic.

1.6. Scope of the Study

The study was starting from further identification the problems of flood hazard, risk and the information gap or awareness level of society of study area. The study is includes, the organization of necessary materials and methods to conduct study, classifying factors, mapping, analyzing, and assessing a flood risk map of Sibu Sire Woreda in particular and flood hazard map for Indris Catchment in general with the application of Multi Criteria Evaluation (MCE) technique in GIS environment. The whole land use/land cover classes, drainage network, elevation, slope, rainfall, soil type, geology, and population data were considered as input parameter (factor) for flood hazard and risk assessment of the Woreda. However, risk mapping depends heavily on models and input data sources, so these are also considered. The KAP study was also evaluated using SPSS software to conduct the awareness level of society. The purpose and efficacy of mapping are also considered in scope.

1.7. Structure of the Thesis

The thesis constitutes of five chapters. The first chapter deals with the introductory part of the thesis such as statement of the problem, objectives of the study, research questions, significance and scope of the study. The second chapter includes review of related literatures which are relevant with the research topic such as, publications, research, booklets and flood risk assessment related notes which is relevant to the thesis. Whereas, the third chapter provides materials and methods, details about the background of the study area such as physical settings including location, topography, soil types, geology, climate, population and agriculture, flood problems in study area. In addition the materials describe detail about the data and software required for this study. And the research methodology and procedures employed to collect data detail. The fourth chapter deals with the data process and analysis, factors to be developed for flood hazard and risk analysis. Chapter five analysis all about the result and discussion which includes all the output discussions of flood hazard, risk and awareness level of society. Finally, chapter six gives brief summary, conclusion and possible recommendation on the results of the study.

2. REVIEW OF LITERATURE

This chapter discusses literature related to the subject of the study. The literature was reviewed under various major headings which included: Nature of flood risks, vulnerability to flood risks, perception of flood risks, behavioral response to flood risks and attitude towards external support.

2.1. Flood Hazard and Risk Assessment using GIS

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 on the map. 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 the impact. Such data will help the planners and decision-makers to take positive and in time steps during pre-disaster situation. It will also help them during post disaster activities for the assessment of damages and losses occur due to flooding (Miller, 1997).

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. When spatial data are used in an information system, one tends to speak of a spatial information system. Spatial data has a physical dimension and geographic location. With the help of sequential images of certain area, we can find out the behavior of the flood routing and damages. Geographic Information System was extensively used to assemble information from different maps, aerial photographs, satellite images and digital elevation models (DEM). Census data and other relevant statistical abstract were also used to make the risk map more oriented to need of the local inhabitants.

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 risk maps for the vulnerable areas. River flooding in the developing countries of Africa is very acute because of their heavy dependence on agriculture but any flood estimation or hazard mapping attempt in this region is handicapped by poor availability of high resolution DEM.

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 (Miller, 1997).

The regulation of flood hazard areas coupled with enactment and enforcement of flood hazard zoning could prevent damage of life and property from flooding in short term as well as in long term. Flood management and control are necessary not only because floods impose a curse on the society, but the optimal exploitation of the land and proper management and control of water resources are of vital importance for bringing prosperity in the predominantly agricultural based economy of this highly populated area. This cannot become technically feasible without effective flood hazard and risk mapping. Flood risk mapping is the vital component in flood mitigation measures and land use planning.

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 Granger, 2002).

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 Granger, 2002), the terms hazard, vulnerability, element at risk, and risk are defined as follows:

Flood risk was analyzed from the following general risk equation (Shook, G., 1997).

$$\text{Risk} = (\text{Elements at risk}) * (\text{Hazard} * \text{Vulnerability}) \dots \dots \dots \text{Equation 1.1}$$

- **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)** mean the population, buildings 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.

2.2. What is Geographic Information System (GIS)?

A GIS could be feeded with relevant information in a standardized form to produce computerized maps and further used for integrated analysis. For instance, the information for flood in GIS could be points (gauge station, structures), line (flood embankments, power lines) and polygon (flooded land, field plots). GIS allows the manipulation of each datum in its entire spatial and temporal context. With this the analysis could be initiated for decision makers (World Bank, 2001).

GIS was acknowledged first by Canada Geographic Information system or CGIS (Peuquet 1977 in Star and Estes 2005). The main aim of CGIS was to analyze Canadian land inventory data, to find marginal lands. Thus, the first GIS were developed to deal environmental problems. It then first implemented in 1964 (Star, J. and Estes, J., 2005).

The commercial development of GIS took place in 1970 during operation of image processing and remote sensing. Several institute and organization were keen in using GIS. Environmental System Research Institute (ESRI) in California used GIS. They used special GIS software like Arc View, Arc Map, Map Info, IDRISI etc. The disadvantage of GIS method is often expensive process of data collection, expensive software system, and complex hardware. It requires an expertise in a variety of geographic, computer science and system engineering field (Star, J. and Estes, J., 2005).

2.3. Data Models in GIS

Computers require unambiguous instructions on how to turn data about spatial entities into graphical representations. At present, there are two main ways in which computers can handle and display a spatial entity, which are also known as data models in GIS. These are the raster and vector approaches to organize the spatial database. In the raster world, individual's cells are used as the building blocks for creating images of points, lines, areas, network and surface entities. In the raster world, the basic building block is the individual grid cell, and the shape and the grouping of cells creates character of an entity. The size of the grid cell is very important as it influences how an entity appears (Heywood et.al, 2002).

The representation of real world phenomena in GIS is in two main types of spatial data representations in GIS are vector and raster data model. *A vector data models* are representation

of real world objects like rivers, buildings etc. in line, polygon and point feature having X and Y coordinate with reference to real world. The point is defined by one single pair of coordinates, lines are defined by two pairs of coordinates and polygon is represented by more than two pair of coordinates forming a closed object.

The vector model is more suitable for mapping discrete geographic objects like river, road and others. A *raster data model* represents earth in forms of grid with equal size of cells in it. Here also like vector data model, features are represented by X and Y coordinates but with only one coordinates in a plane and the cells are defined with the reference to this one coordinates. Each cell contain a numeric value which represent any information of location like elevation, measurements etc. The raster model is used more precisely when working with remotely sensed images and is most suitable choice for modeling continuous geographic phenomena (Heywood et.al, 2002).

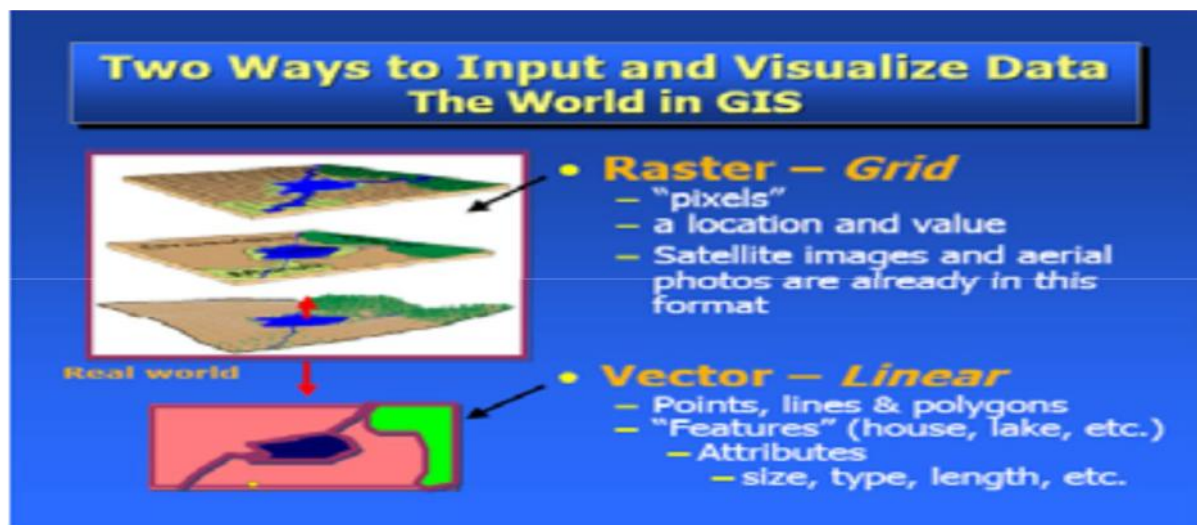


Fig.2.1. Data Models in GIS

2.4. Multi-Criteria Evaluation (MCE)

In Decision theory, Multi-Criteria Evaluation is the process of applying a decision rule to a set of alternatives. A decision rule is a procedure by which criteria are combined to arrive at a particular evaluation, and by which evaluations are compared and acted upon. A decision is a choice between alternatives (such as alternative actions, land allocations, etc.). The basis for a decision is known as a criterion. Criteria may be of two types: factors and constraints. Factors

are generally continuous in nature (such as the slope gradient or road proximity factors); they indicate the relative suitability of certain areas (Heywood et.al, 2002).

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, where by all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection (AND) and union (OR). 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 thresholded 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 overlay (J. Ronald Eastman, 2010). As with all decision making processes, the expert usually engages the decision maker(s) to appropriately structure the problem. AHP (Analytic Hierarchy Process) has the advantage of permitting a hierarchical structure of the criteria, which provides users with a better focus on specific criteria and sub-criteria when allocating the weights. This approach is important, because a different structure may lead to a different final ranking. Criteria with a large number of sub-criteria tend to receive more weight than when they are less detailed. In the application of multi-criteria decision analysis, the analytic hierarchy process, which is a structured technique for dealing with complex decisions, was applied in structuring the flood causative factors. Theoretically, the AHP rather than prescribing a correct decision, aids decision makers find the one that best suits their needs and their understanding of the problem. This implies that AHP is a decision making approach based

on the genuine ability of people to make critical decisions. It allows the active participation of decision makers in exploring all possible options in order to fully understand the underlying problems before reaching an agreement or arriving at a decision (Eastman, 2010). Therefore, the purpose of AHP is to judge the given alternatives for a particular goal by developing priorities for these alternatives and for the selected criteria.

The technique used in this thesis and implemented in IDRISI-32 software is that of pair wise comparisons developed by (Saaty, 1999) in the context of a decision-making process known as the Analytical Hierarchy Process (AHP) (J. Ronald Eastman, 2010). 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 in (table 2.1) below.

Table 2.1. Ratings on a 9-point continuous scale

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very strongly	Strongly	Moderately	Equally	Strongly	Moderately	Very strongly	Extremely
Less important					More important			

2.5. Remotely Sensed Data and Image Classification

Remote Sensing (RS) technique is one of the valuable tools for assessing the water induced hazard and risk. Remote Sensing techniques are used for extracting the information from the data obtained from sensors onboard remote platforms generally satellites and aircraft. With the improvements in the resolutions of imageries and possibility of stereo capability and digital image processing method, the use of satellite imageries has become increasingly important for hazard and risk assessment. For planning the flood control and related works, reliable and timely information about flooded areas, river behavior and configuration prior to floods, during the floods and after the floods is required, such information is very difficult to acquire through conventional ground surveys. Advent of satellite remote sensing technology has helped in

solving the problems of mapping, monitoring and management of floods/flood prone areas (Lillesand, 2000 and 2004).

According to (Lillesand, 2000 and 2004) Satellite images are available from a number of different channels which are used individually or in combination to reveal information about the atmosphere and surface. Two of these channels are commonly referred to as visible and Infra-red images. *A visible image* is one type of radiometer measures visible light and provides visible images (just like a camera taking black and white photographs). What is being viewed is sunlight that has been reflected from the Earth or clouds. *Infrared images* are effectively measuring the temperature of the top of the cloud or, if no cloud is present, of the Earth's surface. The images are usually prepared in such a way that cold surfaces appear white and warm ones darker. Because of the adiabatic lapse rate, temperatures in the lower part of the atmosphere normally decrease with height, so high cloud (with low temperatures) appears white, with low cloud or the Earth's surface appearing darker. Unlike visible images, infrared images are available even when there is no daylight.

A combination of visible and infrared images is very useful and can help distinguish between high and low cloud. For example, if a bright area appears on both the infrared and visible images in the same place, it is likely to be thick, high cloud. However, if the area appears bright on the visible image but dark on the infrared one, it is probably low cloud or perhaps fog. On the other hand, high-level cirrus cloud is readily detected on an infrared image but, unless quite thick, is barely detectable on a visible image.

Pre-processing is done before the main data analysis and extraction of information. Preprocessing involves two major processes: geometric correction and radiometric correction or haze correction. During recording spectral reflectance, atmospheric effects on energy illumination from ground features or geometric distortion can be built up due to high altitude, etc. So the image should be corrected from these distortions. The images of the Sibu Sire Woreda were checked on anomalies caused by this energy interaction in the atmosphere. Image enhancement is used in order to increase the details of the image by assigning maximum and minimum brightness values to maximum and minimum display values, and it is done on pixel values. This makes visual interpretation easier and assists the human analyst. Histogram

equalization is done on the images, where enhancement assigns more display values (or ranges) to the frequently occurring portions of the histogram.

Image classification serves a specific goal: converting image data in to thematic data. In the application context, one is rather interested in thematic characteristics of an area (pixel) rather than in the reflection values. Thematic characteristics such as Land use/land cover can be used for further analysis and input into GIS based models. In addition, image classification can also be considered as data reduction: then multi spectral bands result in a single band raster file.

With a particular application in mind, the information classes of the interest need to be defined and their spatial-temporal characteristics assessed. Based on the characteristics the appropriate image data can be selected. Selection of the adequate data set concerns the type of sensor, the relevant wavelength bands and the date of acquisition (Lillesand, 2000 and 2004).

Satellite images of Landsat, path 168 and row 53, which is acquired on October, 2013 (with a map projection of UTM_ zone 37, spheroid and datum Adindan) have been used for the Land use/land cover mapping which is used as a factor in flood hazard (level of abstraction of rain water and flood risk (element at risk) map preparation. These images were stacked in the ERDAS IMAGINE 2014 software and subset by the boundary of the Indris Catchment. The processes of this classification were discussed later in chapter four.

2.6. Digital Elevation Model (DEM)

A digital elevation model (DEM) is a digital representation of the terrain elevation, or topographic surface (Lovett, 2008 and Shamsi, 2005). It is a major component of a GIS, because it enables elevation data to be used for modeling and analysis and it can also display phenomena, related to topography. DEM are widely used in determining terrain attributes, such as slope, aspect and elevation values, at any point. There are various applications, such as delineation of watersheds and streams and the generation of isometric projections of terrain profiles (Cochrane and Flanagan, 2000, Shamsi, 2005).

DEM can be obtained and created through the interpolation of contour data from topographic maps, or it can be acquired through remote sensing satellites. Amongst the most popular and widely available elevation data sets are those produced by Shuttle Radar Topography Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER

GDEM web site) projections undertaken by United States National Aeronautics and Space Administration (NASA). The ASTER GDEM has a global terrain elevation measurement or resolution of 30 meters interval. The determination of watershed and catchment boundaries is important, in hydrological studies. These watersheds are used in various studies involving water availability and quality projects, flood forecasting programmers' and public policy applications.

However, with the advent of GIS, functionalities such as ArcGIS Hydro, have automated the delineation of watershed and drainage areas. The use of DEM entails the analysis of grids, in order to identify flow direction and accumulation areas, which are then easily, processed with GIS hydrology tools (Mel ancon, 1999). Comparatively, automated delineation, with the use of DEM, provided more accurate results and it could be easily repeated (Kraemer and Panda, 2009) Precise drainage boundaries are essential, for accurate modeling studies.

Digital elevation model 30m resolution, which is acquired on August, 2016 (with a map projection of UTM_ zone 37, spheroid and datum Adindan) have been used for elevation, slope, and drainage density mapping from stream network which is used as a factor in flood hazard. These DEM were stacked in the GIS software and Reclassified by the boundary of the Indris Catchment. The processes of this classification were discussed later in chapter four.

2.7. Flood and Related Issues

2.7.1. Overview

Several authors have put forward a number of definitions of a flood relating to overtopping of river or stream banks, inundation by tidal waters or water from any source, statistical occurrence and economic loss. An analysis of the definitions shows that the authors adopt those definitions that are relevant to their study areas.

For the lower Limpopo basin, Mozambique and United Nations Development Programme (UNDP, 2000) defines a flood as an unusually high stage of a river where the river channel becomes filled with water and above which it overflows its banks. The US Geological Survey Kansas Water Science Centre (undated) defines a flood as an overflow or inundation that comes from a river or other body of water and causes or threatens damage. When carrying out

an impact assessment of flooding in the Nuna valley in Bangladesh, (Leslie, A., 2006) defined flooding as water being found where it is not wanted.

Flood is a temporary condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation or runoff. Flood phenomenon is considered as one of the worst hazards in terms of magnitude, occurrence, geographical spread, loss of life and property, displacement of people and socio-economic activities (Myers and White, 1993).

Flood can be defined as any relatively high water flow that overtops the natural or artificial banks in any portion of a river or stream. People may be washed away in a short span of time, and properties may be heavily damaged by flood. When a bank is overtopped, water spreads over the flood plains and generally becomes a hazard. Flooding is the most common environmental hazard due to the widespread geographical distribution of river valleys and coastal areas. By attraction of human beings to such areas for settlements and farming make it as a fatal obstacle to social progress both in developing and developed countries (Jayaseelan, 2001).

2.7.2. Causes of Floods

Numerous factors affect stream flow, and therefore the potential for flooding. Most important are amount and type of precipitation, the nature and condition of the drainage basin, and climate. Climatic conditions include severe thunderstorms, tornadoes, tropical and extra-tropical cyclones (many of which can be exacerbated by the El-Nino phenomenon), monsoons, ice jams as well as structural failure of reservoirs. Although flooding occurs most commonly from heavy rainfall when natural, watercourses do not have the capacity to convey excess water, floods are not always caused by heavy rainfall (Matiki, 2005).

Dam failure is one way in which an area downstream can be flooded even in dry weather. Floods can also occur as a result of backflow of water from a flooding river without any rains falling, which was the case in Namibia in the Caprivi region in 2004 (Nheta, 2003). Factors which influence whether a flood will occur, include volume, spatial distribution, intensity and duration of rainfall over a Catchment, the capacity of the water course or stream network to

convey runoff; Catchment and weather conditions prior to a rainfall event; ground cover; topography and tidal influences (Vilanculos, 2006).

Stream flow at any given point in a channel depends on the interaction of a number of factors, the most important of which are: distribution, intensity and duration of precipitation, vegetative cover, soil type, and geology of an area and topography; which includes elevation, slope and channel characteristics (Teller, 1967). Poor land use can impact on water resources by altering the hydrology (run off, infiltration and recharge rates) and increase soil erosion leading to increased sediment transport and deposition (Hirji , 2002). The environmental factors whose relationship with flooding will be established include: soil type, slope, distance away from the stream or channel and height above channel base. The other environmental factors which are equally important in determining flooding in an area include geology of an area, vegetation and topography (Miller, 1997).

Different types of soil have different rates of infiltration and water holding capacities of which if the infiltration capacity is exceeded, overland flow results (United Nations, 1997). Soils are derived from the rock types in a particular area and therefore geology directly affects the rate of infiltration of water (deep percolation). Pervious rocks allow increased deep percolation while the less previous ones like granite result in increased overland flow. Land cover does impact on soil's infiltration capacity. Runoff is typically low in areas where the percentage of vegetation cover is high, as vegetated areas allow high infiltration until the earth is saturated as runoff is spread over a long period while increased overland is expected for bare ground. Where the ground is pre-saturated, such as following a long wet period, medium rainfall events can cause flooding as runoff begins almost immediately. There is evidence that land use changes influence the hydrological regime of various river basins (Ashagrie, 2010) which triggers the risk to flooding as a result of increased runoff and subsequent flood levels especially where vegetation is removed to make room for settlement or agriculture. The passage of water tends to be retarded in basins with many natural storage areas such as lakes and wetlands and even those with artificially created storage. Slope plays an important role in the time of concentration, which is the time between the center of excess rainfall and the inflexion point on the recession limb of the hydrograph.

2.7.3. Types of Floods

The most common types of floods in Ethiopia are riverine, rain induced flash floods and the floods that occur as a result of dam failure. Riverine flooding occurs in relatively low-lying areas adjacent to streams and rivers. A flash flood is a local flood of short duration (usually less than six hours) with a relatively high peak discharge generally resulting from heavy rainfall in the immediate vicinity and there is usually little or no advance warning (Miller, 1997).

Flash floods can occur after a heavy storm, after a period of drought when heavy rain falls onto very dry, hard ground that the water cannot penetrate and they can occur almost anywhere. Although flash floods are localized, they pose a significant threat to the loss of human life and property because of their unpredictability and the short duration of the event. (Miller, 1997). Observed that during flash flood events, the capacity of the drainage system has insufficient time to cope with the downpour. An area which has not been flooded in the past is not excluded from possible flooding in the future.

2.7.4. Problems Caused by Flooding

Floods have the greatest damage potential of all natural disasters worldwide and affect the greatest number of people (UN, 2004). When floods occur in less developed nations they can effectively wipe out decades of investments in infrastructure, seriously cripple economic prosperity and result in thousands of deaths and epidemics. Depending on the context, flood flows can be a problem or a disaster. Floods are a problem when the magnitude and impacts of their occurrence exceeds the ability of affected communities to cope or they become a disaster when an event leads to a serious disruption of the functioning of a community or society causing widespread human, material, economic and or environmental losses, which exceed the ability of the affected society to cope using their own resources. Such destruction can impact negatively on socio-economic development of the immediate community and the environment and the country at large. (Barret and Curtis, 2001), define a disaster as a serious, damaging effect on human life, property or activity which results from the impact of a hazard that has exceeded its critical levels.

The socio-economic impacts of floods include loss of life and property, mass migration of people, food shortages, shortage of clean water supplies (deterioration of water quality), loss of proper sanitation facilities and increased incidence of waterborne diseases (World Meteorological Organization, 2010). It is clear that flood losses reduce the asset base of households, communities and societies by destroying standing crops, dwellings, infrastructure, machinery and buildings (UN, 2004).

(Matiki, 2005) Observed that flooding also exacerbates poverty because of the loss of property and other necessities which would have been accumulated over a long period of time, such that any income available in the home when floods occur would have to be used to meet the immediate demands when it could have been used for other necessities. (Matiki, 2005), also observed that flooding has a negative impact on school attendance because school children cannot cross flooded rivers. The environment has its own share of problems that are brought about by floods and these include mass migration of wildlife, inundation of ecologically sensitive areas and environmental degradation. Although floodplains expose their occupants to floods, they offer an enormous advantage of irrigating agricultural fields as well as bringing in deep fertile alluvial soils which increase agricultural outputs.

According to the World Meteorological Organization (World Meteorological Organization, 2010) floodplains do support high population densities and the Gross Domestic Product per square kilometer is high like in the case of the Netherlands.

2.8. Flooding in Ethiopia

As it has been reported in (UNOCHA, 2010), most lakes are at their peak levels and flooding has already been recorded in Amhara, Afar, Tigray, Gambella and SNNPR. Approximately 43,000 people have been affected of which 17,000 have been displaced. A joint government and humanitarian partners' Flood Contingency Plan launched on 13 August anticipates that an estimated 324,000 people will likely be affected. This scenario assumes the overall impact of the flooding will be 25 percent less than in the 2006 main rainy season. The anticipated reduced impact is expected mainly due to better preparedness and prevention measures.

Flooding has also been reported in parts of Oromia, Somali and Dire Dawa City Administration. In Somali Region, where torrential rains affected communities in several

villages in north-western Shilabo Woreda (Korahe zone) and in Warder Woreda (Warder zone), a joint team including zonal officials was not able to assess the situation in the affected areas as roads have become inaccessible. In Dire Dawa, flash floods from highland rains in East Hararghe (Oromia) coursed through the town, damaging houses, submerging farmlands and destroying the 100-meter-high flood protection wall.

The topography of the town and poor soil and water conservation practices exacerbated the situation. In Oromia, heavy rains caused a landslide in Shalla and Wondo Woredas (West Arsi zone). The Woreda Administration provided emergency food and non-food items to the affected. A team of

Regional Early Warning Department and Disaster Risk Management and Food Security Sector officials are conducting a rapid assessment. Emergency support also continues for 500 flood affected households in Hudet and Moyale Woredas (Somali) and Moyale Woreda (Oromia). A flood watch remains in effect due to the ongoing torrential rains in most parts of the country. The latest National Meteorology Agency (NMA) seasonal outlook forecasts “normal” to “above-normal” rains in eastern Amhara, eastern and southern Tigray, central, eastern and southern Oromia, most parts of Somali and SNNP regions (DPA,2006).

2.9. Flood Events in Sibu Sire Woreda

The Indris, Gawiso, Jalale and Chokorsa rivers has historical events of flooding in the Sibu Sire woreda. Flood in 2013 were mainly caused due to the high rainfall intensity and the lack of embankments along the Indris River. On august 19th, 2013 Indris River overflows and inundated some parts of woreda. Sibu Sire woreda (Agricultural and Rural development, and Disaster Management office record, 2013), states that 10 house collapsed, 2.5km gravel road damaged, 2 wood bridges constructed by human force damaged,25 people were sick, 3 people were die and 19 families were displaced from their home. Total economic loss caused by the event come out at 800,000 Ethiopian birr. The damaged agriculture economies were estimated to 150,000 birr, infrastructure 450,000, Home animals to 100,000 birr, and the house damaged to 200,000 and un-estimated human life.

2.10. Flood Risk Awareness

The word risk has been defined differently among individual, group or institutions. Described as the combination of the probability of an event and its negative consequences (UNIDSR, 2009), risk is deemed to be both as a way of expressing uncertainty, and as a collection of awareness (Raaijmakers et. al, 2008). This means that risk is more related with a judgment rather than a fact (Aven & Kristensen, 2005).

Risk awareness itself, basically means the recognition of potential threat of disaster by individuals or groups (dahal, 2008), which involves the process of collecting, selecting and interpreting signals about uncertain impacts of events, activities of technologies (Wachinger & Renn, 2010). (Palp & Werner, 2006), defines risk awareness as an everyday subjective assessment process that is based on experience and on available information without referring to reliable data, series and complex models. In more sociological terms, risk awareness is a construction process embedded into and determined by society and culture. Therefore, risk awareness implies value judgments. These judgments vary among individuals due to different levels of information and uncertainty, due to different intuitive behavior, and also due to specific power constellations and positions of interest (Messner, 2005). As a consequence, the individuals of a community may assess the risk of being flood very differently, because they do not have the same information about the probability of flood hazards events in their region, Woreda and kebel, about mitigation measures and their effectiveness, and they perhaps have a different historical background regarding the experience of living in a floodplain and of being flooded.

3. MATERIALS AND METHODS

3.1. Research Strategy

To address the stated objective; a large scale flood hazard was conducted for Indris Catchment. A method has been suggested to arrive at the flood risk assessment and awareness level analysis using GIS and SPSS respectively. The important steps used in methodology of this study are: (a) Identifying and selection of the factors and constraint; that used for flood hazard and risk mapping, (b) data and data source, (c) data acquisition, (d) methods of data analysis so as to make thematic maps for the criteria that influence the flood hazard and risk process. The step by step process followed for the present problem is as explained in the following sections.

3.2. Description of the study area

Sibu Sire District is one of the Woredas of East Wollega administrative zone of the Oromia national state, Ethiopia. The Woreda is bordered to East by the Gobu Sayo Woreda, to North by Gudeya Bila and Guto-Gida, to the South by Wama Hagalo and Billo Boshe and to the West Wayu Tuqa woreda of East Wollega of the Oromia national state. The Woreda is located according to UTM coordinate system at about 240000m East to 280000m East and 9880000m North to 1040000m North as shown in (Fig.3.1). The Woreda consists of 19 rural and 2 urban Kebeles. The capital town of the Woreda is Sire which is located at 281 Km distance from the national capital, Addis Ababa and 50km distance to east of Nekemte, the administration town of East Wollega Zone. Elevation in the Woreda ranges from 1336 m to 2500 m. The total area of the Woreda is 1,048.56 Sq.km (104,845.6 hectares). Sire Catchment, drained by Indris and Jalale Rivers, is located according to UTM coordinate system at about 230000m East to 280000m East and 980000m North to 1050000m North (Fig.3.1).

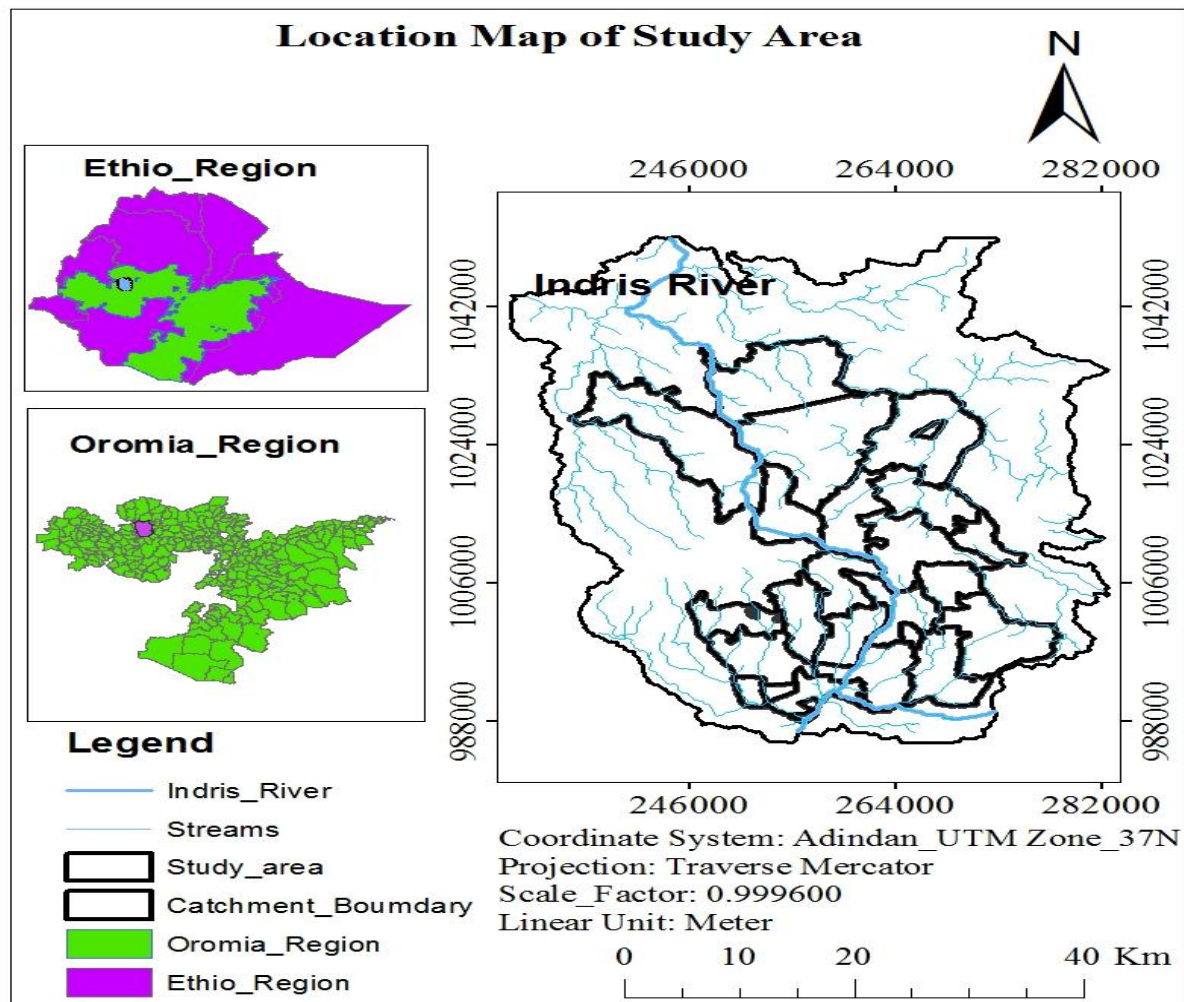


Fig. 3.1. Location map of Sibu Sire Woreda

This Catchment is part of the Abay Basin. It has an area extent of about 157,173.2 hectare. Sibu Sire Woreda is totally lies in this Catchment. This Woreda is found in the downstream part of the Indris rivers. Overflow of these rivers frequently flooded this Woreda than other Woredas in the Catchment, and therefore selected for detailed flood risk study.

3.2.1. Topography

The main land form of the Sibu Sire Woreda is nearly a *slope* having about 0-7.91% with flat plain and sloping relatively rolling. As seen from the (table 3.1) more than 63% of the study area lies within the slope range of 0-26.643 % which is generally flat to gently undulating (rolling) topographic feature.

Table 3.1. Slope Range Distributions of Sibu Sire Woreda

Slope (%)	Class Name	Area in hectare	Percentage
0-7.91	Flat plain	20079.76	19.15
7.91-15.403	Undulating to plain	21185.86	20.21
15.403-26.64	Undulating to rolling	22707.46	21.66
26.64-44.96	Rolling to hilly	20961.96	19.99
>44.96	Mountainous	19910.56	18.99
Total		104845.6	100

Source: Indian, Terrain classification system, 2010

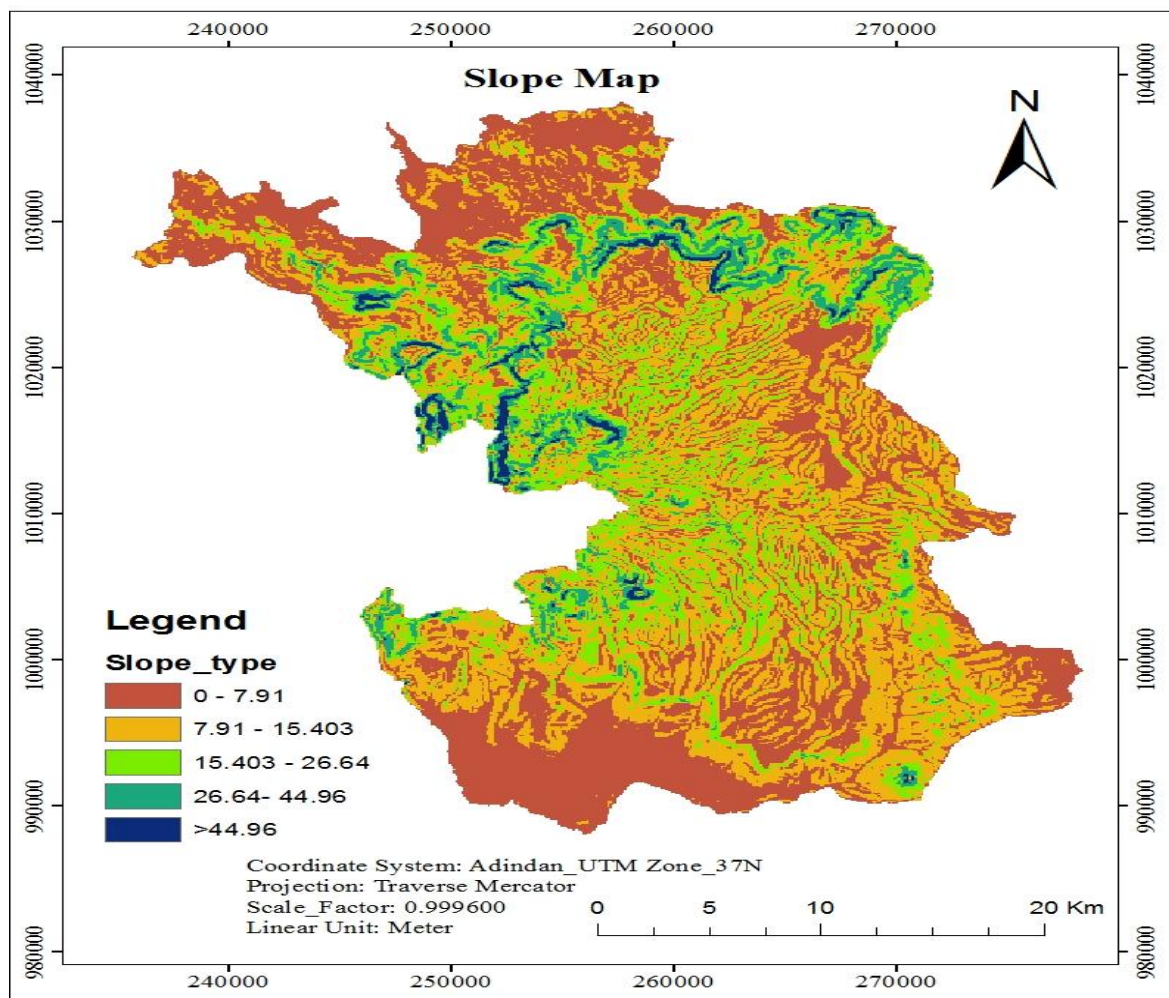


Fig. 3.2. Slope range distribution map of study area (Source: ASTER GDEM Website)

The *elevation* of Sibu Sire Woreda is ranges from 1304 meters above mean sea level, at the North and south-West part of the Woreda area, to 2970 meters above mean sea level at center of the western part as shown in (fig.3.3).

Table 3.2. Elevation range Distributions of Sibu Sire Woreda

Elevation(m)	Area in hectare	Percentage
1250-1425	29239.64	27.888
1425-1597	28518.2	27.200
1597-1822	31695.62	30.231
1822-1981	12271.3	11.704
1981-3156	3120.822	2.977
Total	104845.6	100

Source: Indian, Terrain classification system, 2010

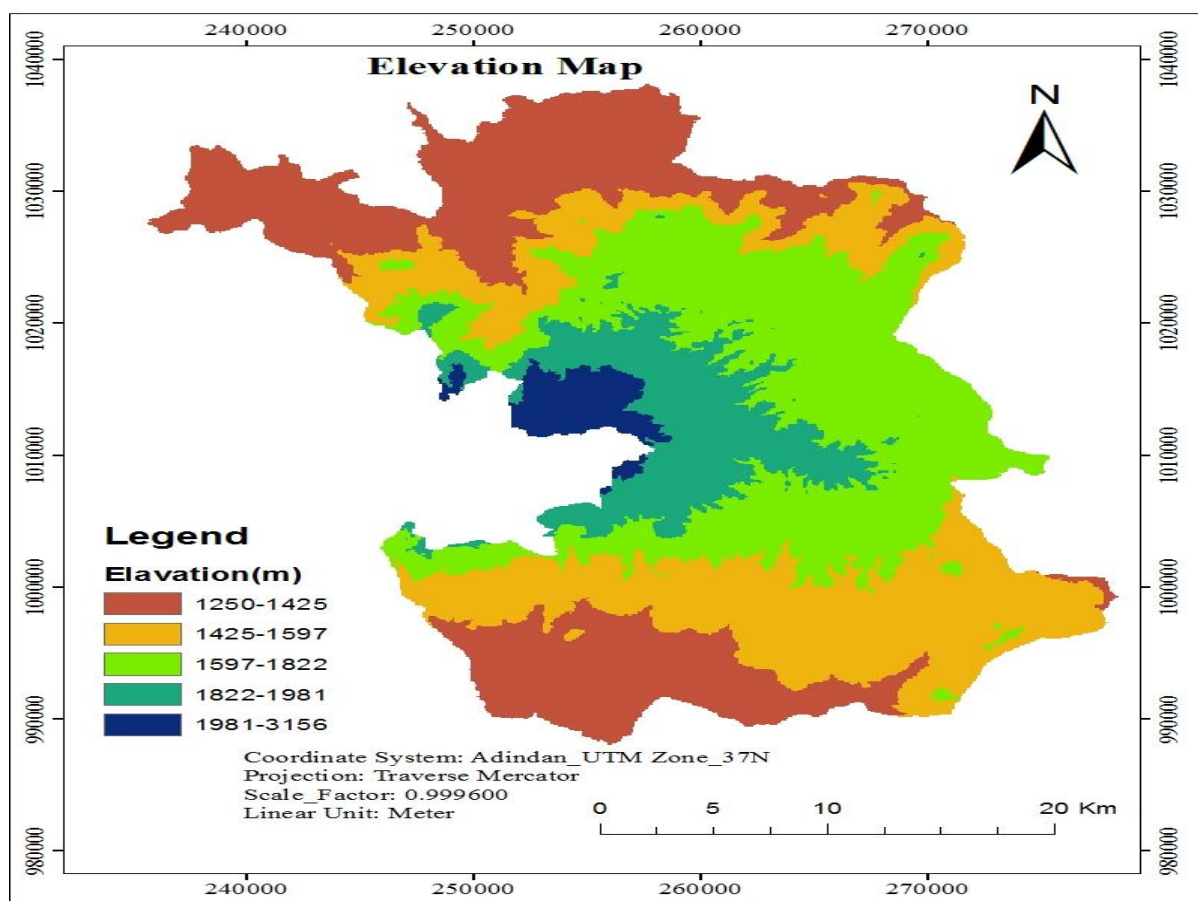


Fig.3.3. Elevation range distribution map of study area (Source: ASTER GDEM Website)

3.2.2. Soil Type

Although there is a wide range of soil types, the soil type of the study area was derived from the FAO standard classification of Ethiopian soil. These soil types are Dystric Nitisols, Lithosols, and Eutric Nitisols. Dystric Nitisols are the dominate soil type in the study area. Most of the soils of Sibu Sire Woreda formed from the volcanic rocks are inherently fertile. Dystric Nitisols and Lithosols are generally dominating in the Woreda and particularly the lowland flat plains, valley bottoms and river terraces. Shallow Pellic Vertisols are the dominant soil types found in the mountain and hills of the study area (fig.3.4) below.

Table 3.3. Soil type of Sibu Sire Woreda

Soil type	Area in hectare	Percentage
Dystric Nitisols	95344.2	90.938
Lithosols	5822.64	5.554
Pellic Vertisols	3678.75	3.509
Total	104845.6	100

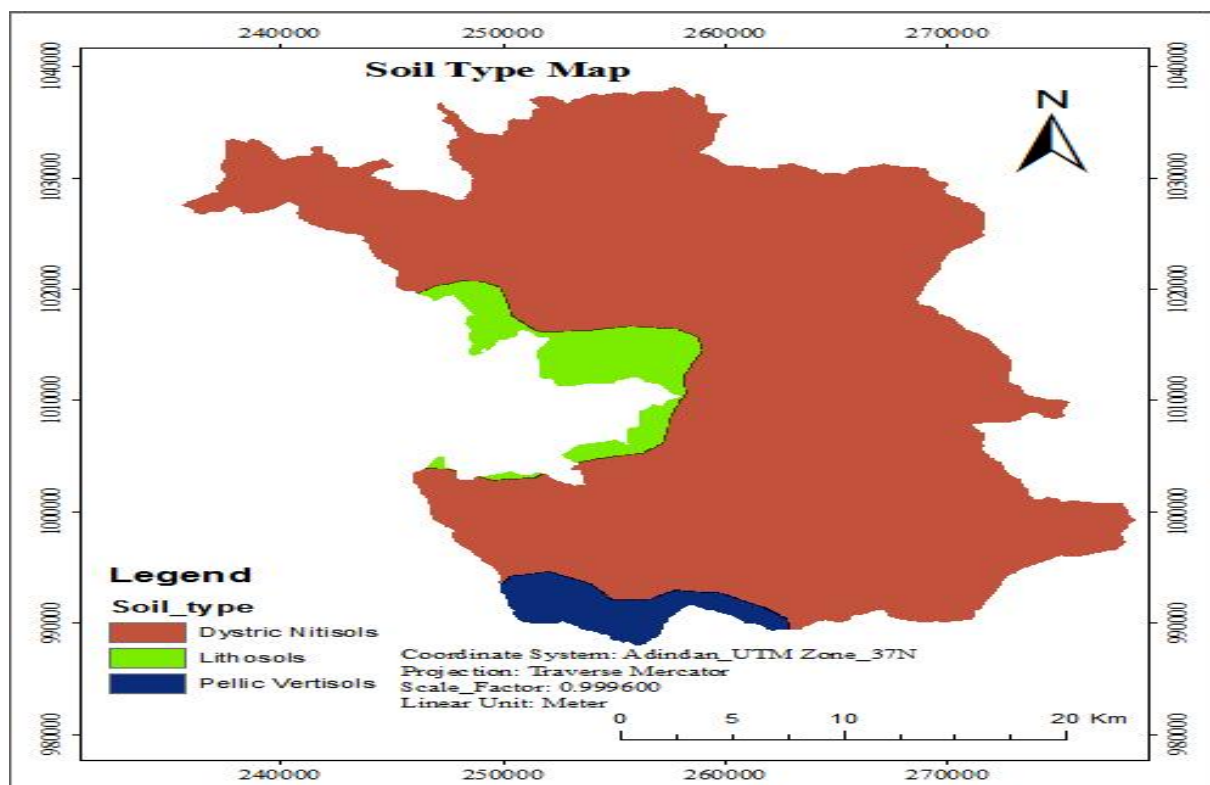


Fig.3.4. Soil types of Sibu Sire Woreda (Source: Ethiopian Ministry of water and Energy)

3.2.3. Geology

The Precambrian rocks of Western Ethiopia was also studied and classified into three N-S running zones: the western high grade gneisses, the central low-grade volcano-sedimentary belt and the eastern high-grade belt, the low-grade volcano-sedimentary belt bounded both to the east and west by high-grade gneisses (Amenti Abraham, 1989). The Nekemte area is indicated to be part of the eastern bounding gneiss. Accordingly there are five types of geological structure on the Sibu Sire Woreda namely, Adigrate sandstone, Wollega basalts, Undifferentiated related to volcanic, Basalts related to volcanic and Colluviums of geology type, and Wollega basalts are the dominate geology in the study area as shown in (Fig.3.5).

Table 3.4. Geology type of Sibu Sire Woreda (Source: Ethiopia Geological Survey)

Geology type	Area in hectare	Percentage
Adigrate Sandstone	11013.30	10.504
Wollega basalts	18854.28	17.983
Undifferentiated related to volcanic	72080.82	68.749
Basalts related to volcanic	2637.36	2.515
Colluviums	259.84	0.248
Total	104845.60	100

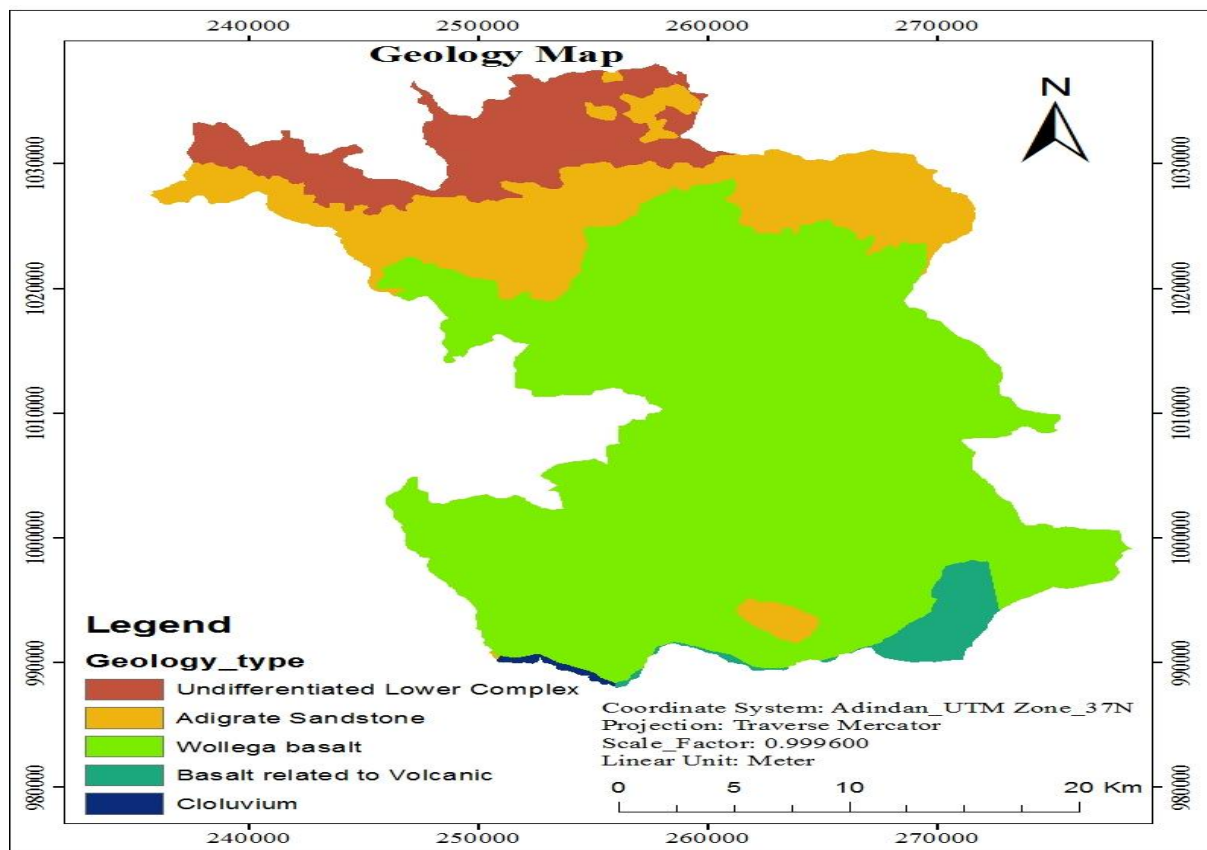


Fig.3.5. Geological map of Sibu Sire Woreda (Source: Geological Survey of Ethiopia)

3.2.4. Climate

Rainfall data from the Six Metrologic stations Nekemte, Ijaji, Ambo, Gida-Ayana, Arjo and Bedelle 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; while months from November to February are dry. The long rainy season in the area is between May to September, during which crop cultivation takes place in the Woreda. Monthly rainfall data was available for the years from 1993 to 2013 at Metrologic station of East Wollega. The total annual rainfall 1295mm (Appendix 3).

The highest mean maximum monthly *temperature* was generally observed during the dry season. In the Sibu Sire Woreda, the mean maximum temperature was greater than 30°C, occurred during February to August, while the mean minimum temperature was less than 15°C occurred during December to February as shown in (appendix 5).

3.2.5. Population and Agriculture

The total number of population in the Woreda is 102,228, amongst 50,717 are male 51,511 are female and 10,243 are urban dwellers while 91,985 are rural dwellers as shown in (Appendix 4). The Woreda is the second among the 18 Woredas in East Wollega zone of Oromia region. The crop production practice is mainly dependent on a traditional rain fed agriculture in which all cultivation is done by traditional methods and practically no modern agricultural production inputs are applied. Similarly the farmers in these peasant associations also practice farmer herding due to the suitability of the climate and as an alternative source of livelihood (Daniel Ebba, 2008).

3.2.6. Land use /Land Cover

The land use/land cover pattern of the Sibu Sire Woreda has five categories, namely such as Dense/Sparse vegetation, Scrub/Fallow land, Agricultural land, Settlements and Water Bodies. Form these land use/land cover classes the dominant one is Agricultural land. It covers about 34.58% of the total land area as shown in (table 3.5). Land use land cover map of the study area was shown in (Fig. 3.6).

Table 3.5. Land use/Land cover of Sibu Sire Woreda

S.N	Land use /Land cover	Area in hectare	Percentage
1	Water body	2149.30	2.05
2	Settlements	2677.68	2.55
3	Agricultural Land	42364.62	40.41
4	Scrub/Fallow Land	38680.47	36.89
5	Dense/Sparse Vegetation	18973.53	18.10
Total		104845.6	100

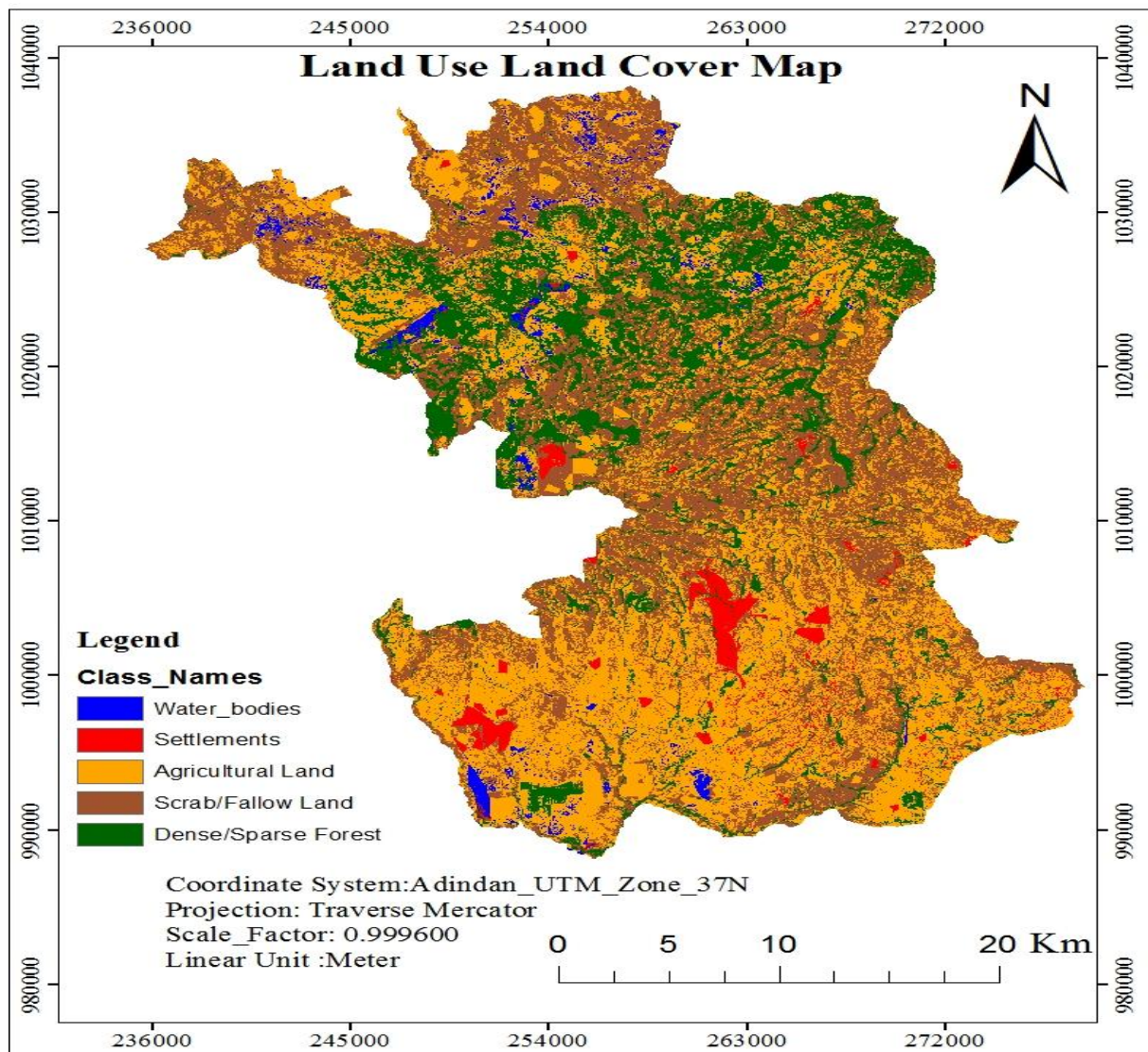


Fig.3.6. Land use/Land cover of Sibu Sire Woreda (Source: UGS.gov 2016)

3.2.7. Flood problem in the Study Area

Flooding has been a problem in some parts of Sibu Sire Woreda in Indris Catchment having the natural topography, which varies from the very mountainous to the very flat lands. The flat lands of the Catchment are found in Sibu Sire Woreda and hence it is severely affected by flooding every year. Indris Catchment has a drainage area of 157,173.2 hectare. There are some streams feeding it. The major stream feeding the Catchment comes from the nearby highland at a higher elevation than the Catchment. During rainy seasons, the level of Indris and Gawiso rivers rises. As a result, it inundates low lying areas of Sibu Sire Woreda.

Flood defenses are laid in advance of flood events. As it was observed during the field survey, flood defense structures built around flood prone areas looked locally and environmentally acceptable. However, the retaining capacity and strength of the structures seemed to be limited in respect of the volume of water intruding those places and the level reached during storm precipitation. In addition, the small defenses constructed through safety net program looked so poor in quality and size. It is, therefore, necessary that special program emphasizing on flood protection be designed in order to lay a ground for constructing dependable and locally sound structures.

3.3. Materials

These describes detail about the data requires for the study and the causative factors required for flood hazard and risk. So these materials are the data collected from their sources includes; data layers, data format, data sources, scale (resolution) of data and purpose of the layer (data). It also includes the software necessary for the study such as, Arc GIS software, Erdas Imagine-2014, Idris-32, SPSS and MS Words. The data and their sources used to generate flood hazard of Indris Catchment and flood risk map of Sibu Sire Woreda are reported below (table 3.6).

Table 3.6. Data type and their sources

Layers	Format	Data Source	Scale	Purpose of the Layer
Land use land cover classes	Raster	Product of satellite image(ASTER GDEM web site)	30*30	To develop flood hazard and risk map
Drainage data	Shape file	FDRE Ministry of water and Energy	-	To develop flood hazard map
DEM	Raster	ASTER GDEM web site	30*30	To prepare elevation and slope map
Population data	Soft copy (Excel format)	CSA	No	To develop flood risk map
Satellite image	.img	USGS.gov	30*30	To prepare land use land cover types
Geological data	Shape file	Ethiopian Geological Survey	-	To prepare flood hazard map

Soil Type	Shape file	Ministry of Water and Energy	-	To prepare flood hazard map
Rainfall data	Soft copy(Excel format)	NMA	-	To prepare flood hazard map
Questionnaire data	Questionnaire form on paper	Interview from sample respondent of Study area people	-	To evaluate the awareness level of society

3.3.1. Software

Software used in this study is selected based on the capability to work on the existing problems in achieving the predetermined objectives. Hence, software package like ERDAS 2014 was used for image processing activities on satellite images for the preparation of land use/ land cover types. The factor map development was carried out using ArcGIS10.1 software package. The factors that are input to for multi-criteria analysis should be pre-processed in accordance to the criteria set to develop flood hazard analysis. So using Spatial Analyst, some relevant GIS analyses were undertaken to convert the collected shape files. Eigen vector for the selected factor was computed using Weight module in IDRISI-32 software. SPSS used for statistical frequency analysis of the KAP data for the existing awareness level analysis of the society of the study area.

3.4. Methods

Flood risk of the Woreda was analyzed from the following general risk equation Shook, (1997).

$$Risk = (Elements\ at\ risk) * (Hazard * Vulnerability)..... Equation\ 1.1$$

The approach adopted in this study in order to reach the objectives of the study is reclassifying, weighting and run Multi Criteria Evolution (MCE).The flood causative factor map development was carried out using Arc-GIS 10.1 software package. The factors that are input to for multi-criteria analysis should be pre-processed in accordance to the criteria set to develop flood hazard analysis. So Eigen vector for the selected factor was computed using Weight module in IDRISI-32 software. The selected flood hazard causative factors such as elevation, slope, drainage density, Land use/land cover, soil type, geology and rainfall. To run MCE, the selected factors were developed and weighted. Then weighted overlay technique was

computed in ArcGIS10.1 Model Builder to generate flood hazard map (fig 4.13). The input datasets are organized in personal geo-data base and then processed to the suitable format, classified, weighted and analyzed. The resulted coverage is created by overlay of these layers and produce flood hazard map.

Considering the degree of loss to be total for the study area, the vulnerability is assumed to be one. Then to generate flood risk map of the Woreda, elements at risk layer (land use land cover and population density) and the flood hazard map were overlaid using weighted overlay analysis technique in ArcGIS10.1 environment (fig 4.14).

3.4.1. Awareness Questionnaire Survey

The questionnaire survey was carried out to conduct analysis of the existing awareness level of the people to the natural hazards such as, flood hazard, vulnerability and risk in the Woreda. Sibu Sire Woreda total populations were 102,228 (CSA, 2007). From this total population 40 sample respondents were interviewed from the 20 kebele about the knowledge, attitude and Action (performance) or (KAP) to flood hazard, vulnerability and risk. Questionnaires were used as a main instrument to collect primary data from the selected sample respondents 40 peoples who are represents total population of Sire town (kebele 01 and 02) and 19 rural kebeles. The KAP random sample systematic questionnaire survey is conducted for the awareness level of society in the Woreda to analysis their knowledge, attitude and action (practice) about the flood hazard, vulnerability and risk to the pre-flooding and post- flooding time, through the semi-structured questionnaire means that the data is collected in the close-ended method (appendix 01).

The questioner is adapted in Afan Oromo and Amharic language and also translated into English language to check the possibility of changing the meaning of the questioner. The data collection unit was every person among the sample. To complete the interview technique were used to collect information about the awareness of flood impacts on their livelihood. The interview was taken from those who fulfilled the inclusion criteria of the study.

The selected inclusion and excluded criteria for collecting sample from populations were considered during data collection. That people who are the affected from the flood and associated factors of flood are included in this study. The age level of the sample is one of the

most important factors and the interview conducted with the age range from 18 to above. The people, those who are diagnosed as the dementia or any other mental health problems, are being excluded from the study (interview).

To find out the study results, code the data and find out themes from those data. In the background characteristics, selected KAP variables or indicators were also included. This was done to assess the awareness among these indicators and the issues under investigation. The weight rank value of each question variables can be determined as 1, 2, 3, 4, and 5 for the very low, low, moderate, high and very high respectively. Software such as excel and SPSS were used to enter and analyses the data.

4. DATA PROCESS AND ANALYSIS

4.1. Introduction

In order to generate flood hazard and risk map, eight interrelated components of the environment were used as input data sets (factors). Accordingly the selected input datasets were drainage density, elevation, slope, land use/land cover, rainfall, soil type, geology and population are used to generate flood hazard and the generated flood map hazard, land use/land cover and population density factor are used to generate a final flood risk map. Each of the factor maps were produced from remote sensing image, topographic maps and different available maps. Before combining them, rasterization was done for the vector data layers in order to produce similar data layers to perform GIS analysis.

Prior to combining the factors, weights have to be given based on Satty' s Analytic Hierarchy Process (AHP), where a pair-wise comparison matrix will be prepared for each map using a nine point importance scale (table 4.10). Weighting is used to express the relative importance of each factor to other. The larger the weight, the more important is the factor in overall utility. The relative comparisons between the eight data layers were performed by asking experts comprising of hydrologists, engineers, end-users and reviewing of literature to give the assessments and judgments regarding the variables related to flooding and their significances in terms of weights.

The standardized raster layers were weighted using Eigen vector that is important to show the importance of each factor as compared to other in the contribution of flood hazard. Accordingly, the Eigen vector of the weight of the factors was computed in IDRISI32 software in Analysis menu Decision Support/ Weight module as shown in (appendix 02). It also calculates consistency ratio that shows if the given pair-wise weights are accepted or if another arrangement is necessary. The comparison conducted indicated that highest weighting for the slope data layer followed by the drainage data layer, elevation data layer, rainfall data layer, soil data layer, land use / land cover data layer and geology data layer.

4.2. Database Design

All the factors were stored in the geo-database in order to store the collected data and the analysis results in a logical arrangement. The factors involved were examined according to

their relative importance towards delineating areas of high flood risk and flood hazard and assigned weights. The classes in each factor layers were also compared one another and ranked by their contribution to the output.

The geographic database (geo-database) is a core geographic information model to organize a spatial data in to thematic layers and spatial representations. Two types of geo-database architectures are available under ESRI's Arc-GIS package: Personal Geo-database and Multiuser Geo-database. In this study, Personal Geo-database was designed in Arc-Catalog to include all the input datasets, their analysis and the final flood hazard, risk map and flood risk impact map. In addition to these, a personal geo-database is used to protect the data from lost and easy access in the GIS tool. Thus, vector files were exported to the corresponding feature data sets and the raster files were exported as individual raster datasets in the personal geo-database. The coordinate system selected to be used for analysis was projected coordinate system, UTM. Thus, the geo-database was set to this spatial reference and all the maps were projected to it while exporting to the geo-database.

4.3. Watershed of Indris Catchment

A watershed is the upslope area that contributes flow generally water to a common outlet as concentrated drainage. It can be part of a larger watershed and can also contain smaller watersheds, called sub-basins. The boundaries between watersheds are termed drainage divides. The outlet, or pour point, is the point on the surface at which water flows out of an area. It is the lowest point along the boundary of a watershed. Hence, in this case watershed of the catchment is used as the background of study area and determine the direction of rivers or streams flow. Considering this first develop the flood hazard map of Indris catchment and specifically develop flood risk of Sibu Sire Woreda. (Fig.4.2) flowchart shows the process of extracting hydrologic information, such as watershed boundaries and stream networks, from a digital elevation model (DEM) (fig.4.3).

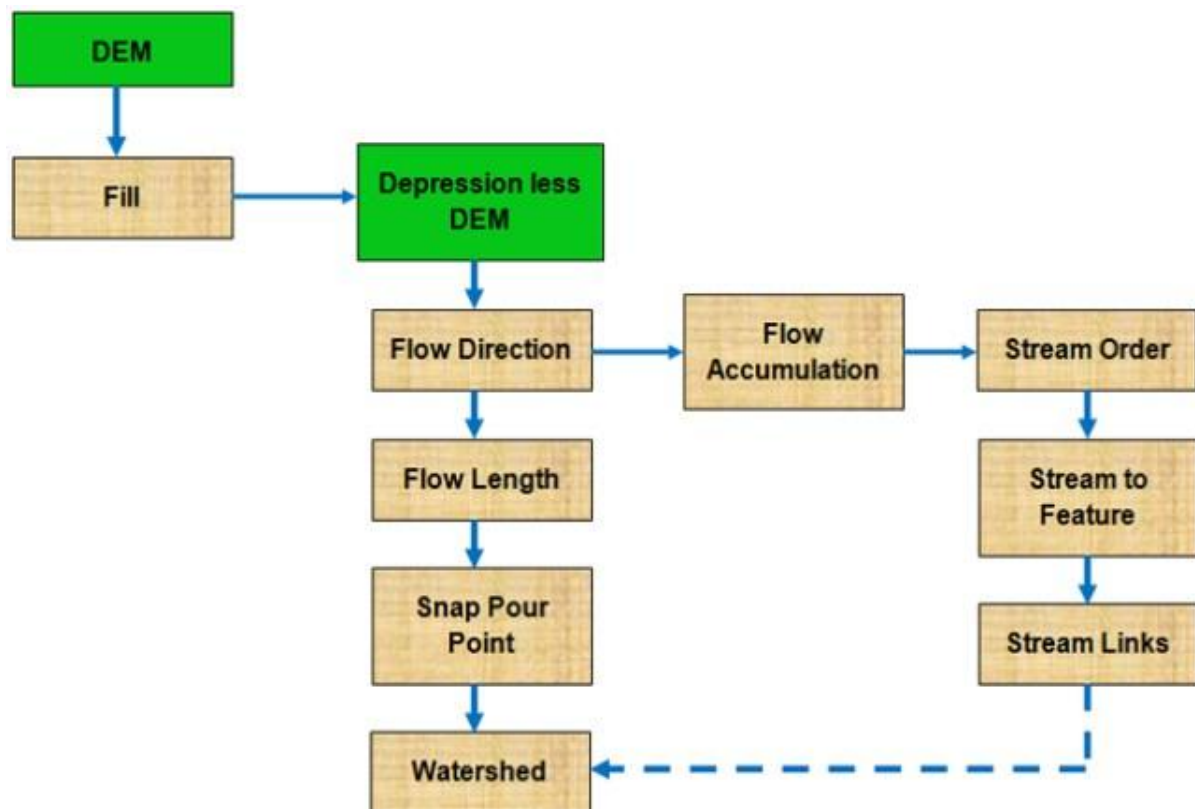


Fig. 4.1. Watershed scheme method.

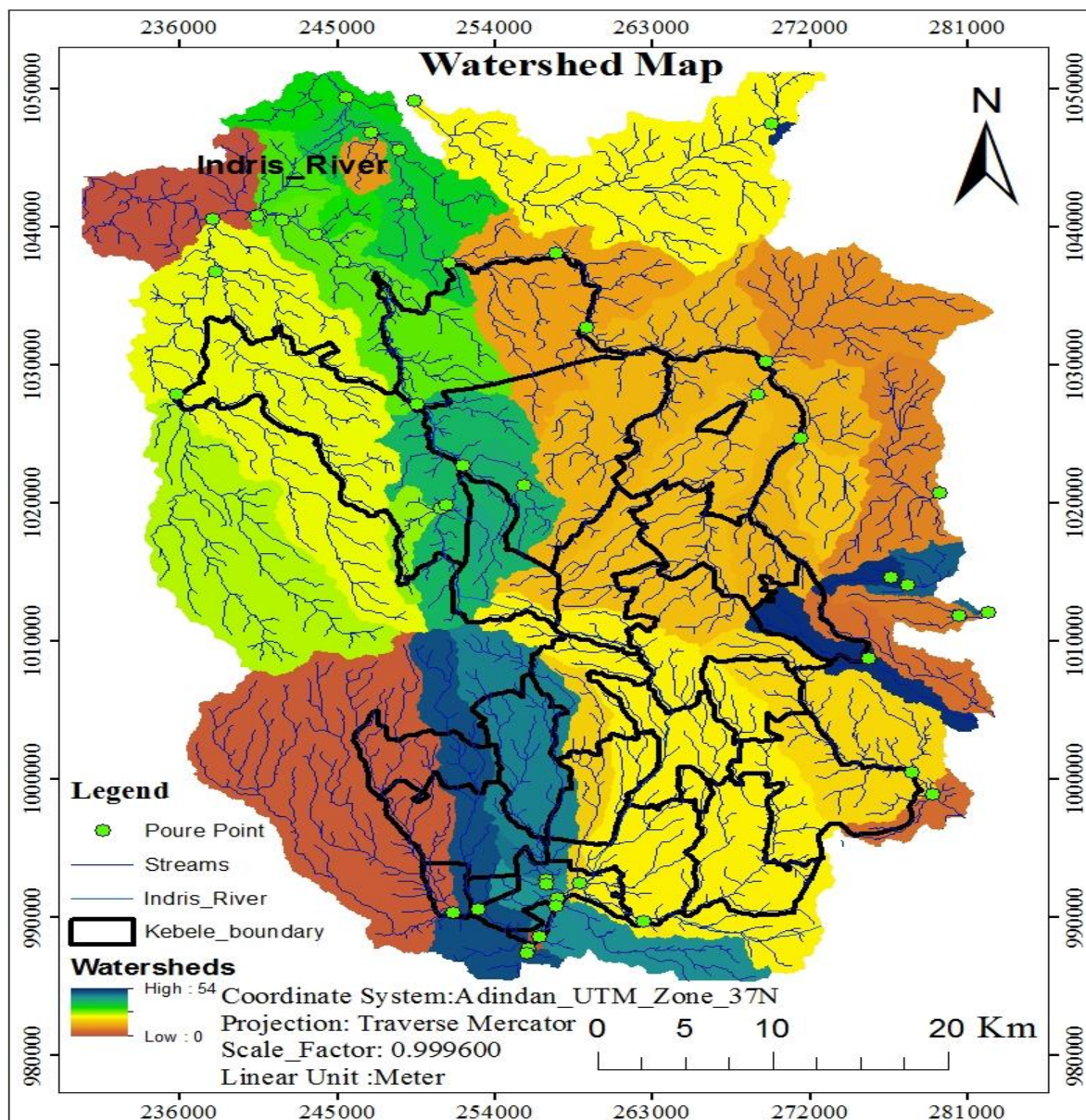


Fig. 4.2. Watershed map of Indris catchment

4.4. Factors Development

Before the factors are merged in weighted overlay analysis, all the input parameters were made to be uniformly scaled. In addition, all the factors have been classified which ranging in accordance with their influence to the flood susceptibility and all the parameters have been reclassified to a similar scale values.

4.4.1. Rainfall Intensity

Heavy rainfalls are one of the major causes of floods. Flooding occurs most commonly from heavy rainfall when natural watercourses do not have the capacity to convey excess water. Floods are associated with extremes in rainfall, any water that cannot immediately seep into the ground flows down slope as runoff. The amount of runoff is related to the amount of rain a region experiences. The level of water in rivers or lakes rises due to heavy rainfalls. When the level of water rises above the river banks or dams, the water starts overflowing, this causes floods (Nicholls, 2001). The water overflows to the areas adjoining to the rivers, lakes or dams, causing floods or deluge.

In the study, it was observed that while the local rainfall is relevant for the flooding, rainfall amounts on the upstream catchments contribute to flood hazard and risk caused by the rivers. Therefore both the local and upstream rainfalls were integrated in the analysis, due to the limited size of the study areas. A mean annual rainfall for twenty years (1993–2013) data has been collected from the NMA within the Indris Catchment and outside the Catchment, of six stations and interpolated using Inverse Distance Weighting (IDW) to create a continuous raster rainfall data within and around catchment boundary. The resulting raster layer was finally reclassified into the five classes using an equal interval (fig.4.4). The reclassified rainfall was given a value 1 for least rainfall to 5 for highest rainfall. (Table 4.1), shows the results of the raster rainfall layer, IDW interpolated data layer and the reclassified rainfall data.

Table 4.1. Reclassification of Rainfall Indris Catchment

Rainfall(mm)	Ranking	Area in hectare	% of area	Level of flood hazard
1456.988-1529.315	1	30833	19.62	Very Low
1529.315-1584.511	2	33003.0	21.00	Low
1584.511-1647.321	3	31275.0	19.90	Moderate
1647.321-1729.164	4	31394.7	19.97	High
1729.164-1940.434	5	30667.5	19.51	Very High
Total		157,173.2	100	

Table 4.1. Indicated that 19.62, 21, 19.91, 19.97 and 19.51 percent of area respectively subjected to very low, low, moderate, high and very high level of flood hazard. This is not meant that there is not much difference between different places of the Indris Catchment. But since the interpolation was made between stations of different distance from each other look exaggerated differences.

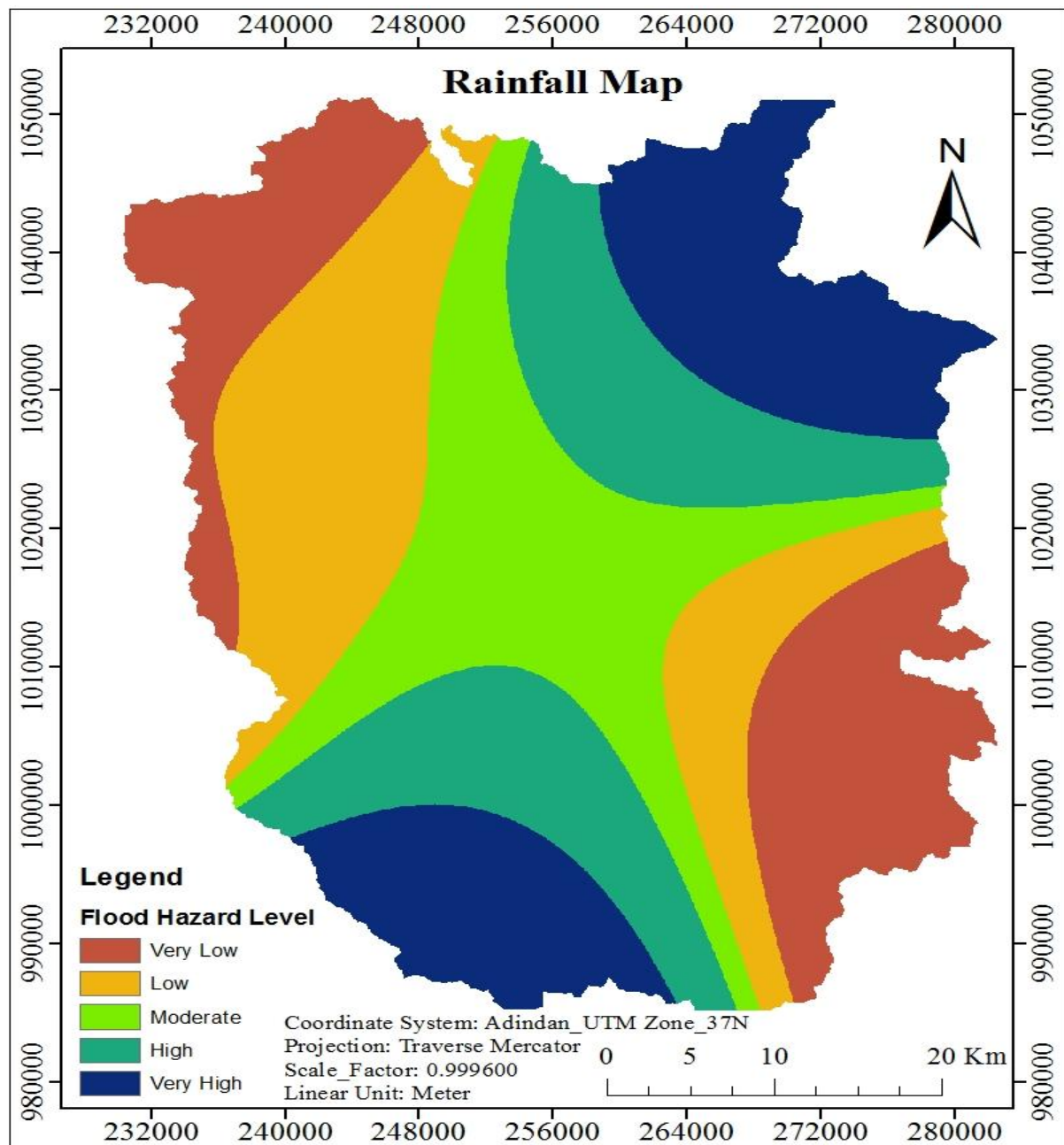


Fig.4.3. Reclassified rainfall map of Indris Catchment

4.4.2. Drainage Density

Drainage is an important ecosystem controlling the flood hazard as its densities denote the nature of the water. This means that the higher the density, the higher the Catchment area is susceptible to flood, resulting inundation at the lower grounds (Strahler, 1999). The first step in the quantitative hazard analysis is designation of stream order (Strahler, 1964). Drainage density map could be derived from the drainage map. *i.e.*, drainage map is overlaid on watershed map to find out the ratio of total length of streams in the watershed to total area of watershed and is categorized. The drainage density of the watershed is calculated as length of lines per unit area: $D = L / A$, where, D = drainage density of watershed; L = total length of drainage channel in watershed (km); A = total area of watershed (square kilo meter).

For the study area, higher weights were assigned to poor drainage density areas and lower weights were assigned to areas with adequate drainage. The drainage density layer was further reclassified in five sub-groups using the standard classification Schemes (fig.4.2). Areas with very low drainage density are ranked as 5 and those with very high drainage density were ranked with value of 1 as depicted in the results (table 4.2).

Table 4.2. Reclassification of drainage density of the Catchment

Drainage Density (km.sq.km)	Ranking	Area in Hectare	% of Area	Level of Flood Hazard
0-0.123	5	9317.7	6.55	Very high
0.123-0.265	4	31376.7	19.96	High
0.265-0.423	3	38385.9	24.42	Moderate
0.423-0.665	2	40075.2	25.50	Low
0.665-1.500	1	37033.2	23.56	Very Low
Total		157,173.2	100	

Table 4.2 reveals that the drainage density value under 0 to 0.123km/sq.km within very high level of flood hazard occupies an area about 6.55 percent. It is evident that the large portion of area about 85612.87 hectare (34.07 percent) occupied between 0.265 and 0.423 km/sq.km of drainage density value. At the same time drainage density value ranged from 0.423 to

0.665km/sq.km covered an area approximately 53331.03 hectare (21.22 percent). Only 6.55 percent area recorded very high drainage density value between 0 km/sq.km and 0.123 km/sq.km classes within very high level of flood hazard.

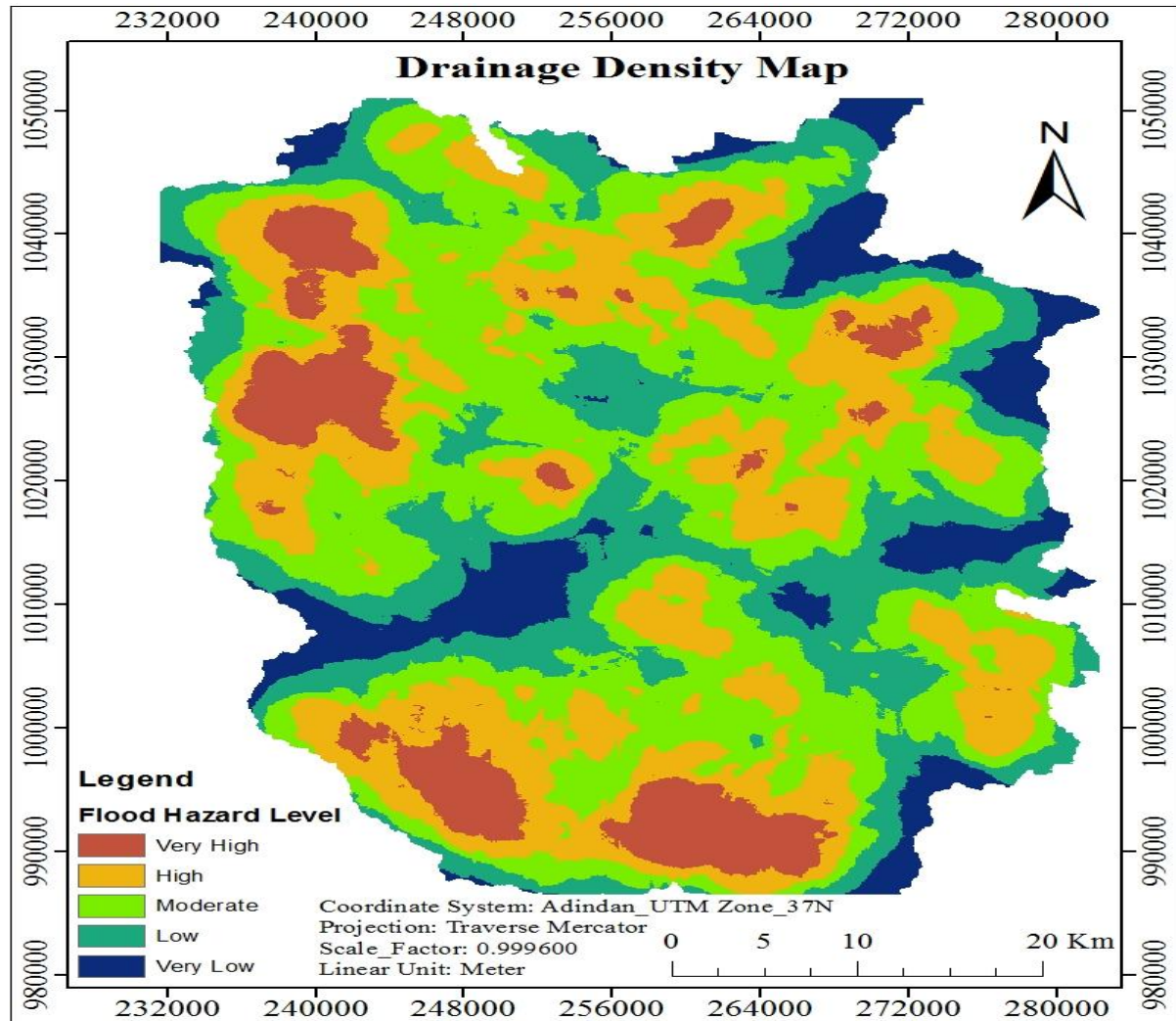


Fig. 4.4. Reclassified drainage density map of Catchment

4.4.3. Slope

Slope plays an important role in governing the stability of a terrain. Slope has a dominant effect on the contribution of rainfall to stream flow. It controls the duration of overland flow, infiltration and subsurface flow. Combination of the slope angles basically defines the form of the slope and its relationship with the lithology, structure, type of soil, and the drainage. A smooth/flat surface that allows the water to flow slowly is not desirable and causes flooding, whereas a higher surface roughness can flow down quickly the flood response and is desirable.

Steeper slopes are more susceptible to surface runoff, while flat terrains are susceptible to water logging (Krumbein, 2002). Low gradient slopes are highly vulnerable to flood occurrences compared to high gradient slopes. Rain or excessive water from the river always gathers in an area where the slope gradient is usually low. Areas with high slope gradients do not permit the water to accumulate and result into flooding.

The slope of the Indris Catchment is extracted from a 30 meter resolution DEM of the area which is downloaded from ASTER GDEM web site. The slope raster layer was further extracted to the catchment area using the Arc-GIS spatial analyst tool and the slope was generated using 3D analyst tool raster surface. The slope raster layer was further reclassified in to five sub group using standard classification schemes. 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, the slope classes having maximum value was assigned to higher rank because areas with high slope gradients do not permit the water to accumulate and result into flooding, while the class having less value was categorized as lower rank due to relatively high run-off. For the case study, the results of reclassified slope layers are presented in (fig. 4.6).

Table 4.3. Reclassification of slope of the Catchment.

Slope (%)	Class_ Name	Ranking	Area in hectare	% of Area	Level of Flood Hazard
0-7.909	Flat Plain	5	30932.44	19.68	Very High
7.909-15.403	Undulating plain	4	32705.44	20.81	High
15.403-26.643	Undulating rolling	3	34060.44	21.67	Moderate
26.643-44.96	Rolling to hilly	2	35318.44	22.47	Low
>44.96	Mountainous	1	24156.44	15.37	Very low
Total			157,173.2	100	

Table 4.3, Indris Catchment is characterized by five classes of slope factor. It is evident that the area is largely flat as low and nearly low (undulating) slope classes together occupy about 41 per cent area. It is also noted that about 44 percent area fall under moderate (Undulating to

rolling) to steep slope (Rolling to hilly) classes and about 15 percent area fall under very steep slope (mountainous) classes.

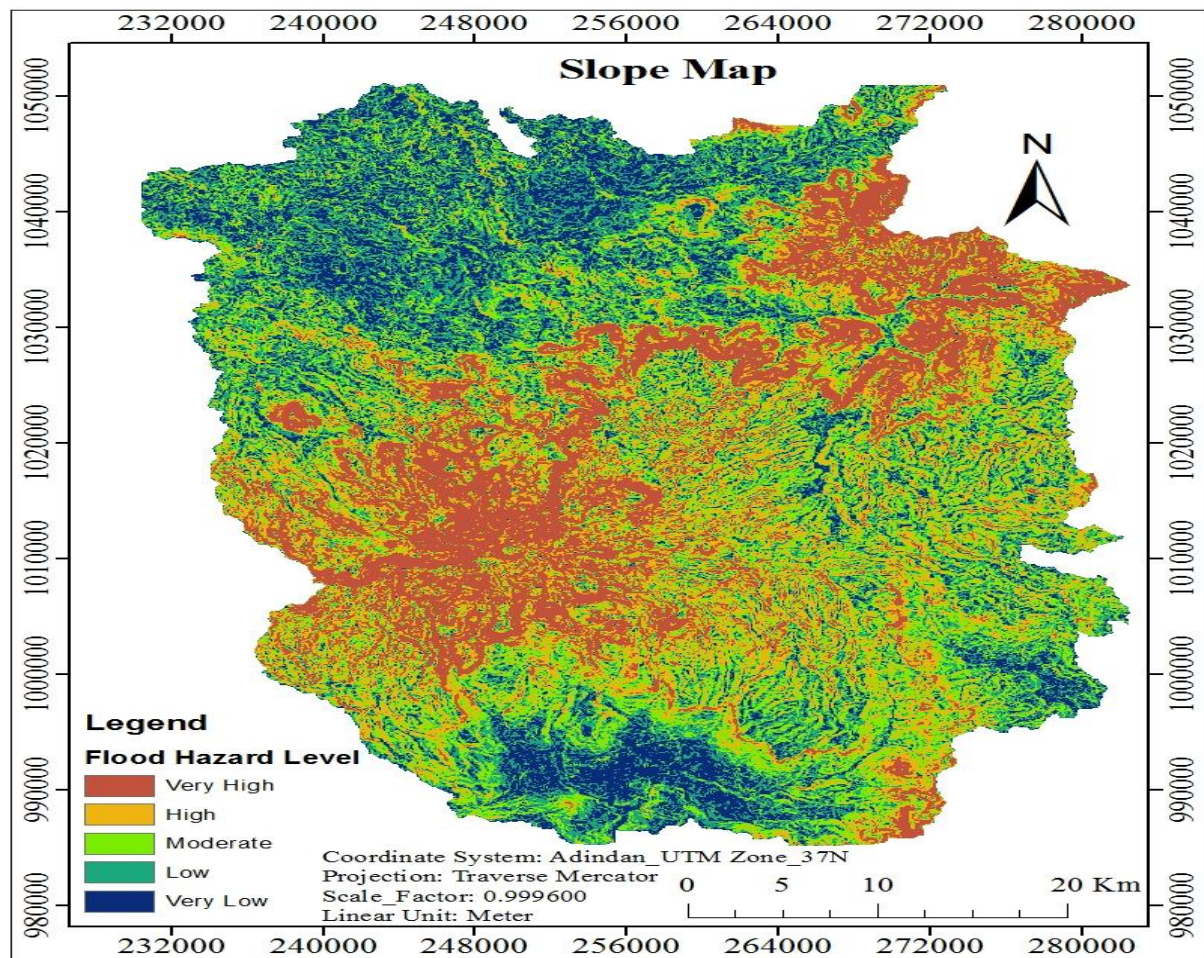


Fig. 4.5. Reclassified slope map of the Indris Catchment

4.4.4. Elevation

Elevation, as an intensifying factor, plays an important role in flood severity and for the determination of a flood prone area. Elevation has a direct effect on flow size and runoff velocity and flood-prone areas mostly have low elevation (Krumbein, 2002). The elevation of the Indris Catchment is extracted from 30 meter resolution DEM of the catchment area downloaded from ASTER GDEM website. Elevation of the catchment area was masked by Arc-GIS spatial analyst tool.

In this classification process an area at lowest elevation is strongly affected by flood and hence ranked to 5 while an area at relatively higher elevation is the least to be affected by flood and

hence ranked to 1. (Fig.4.7), the elevation of Indris Catchment is ranges from 1250 meters above mean sea level, at the some parts of West to central and Eastern parts of the catchment area, to 3156 meters above mean sea level at the Northern and some parts of the south parts of the catchment area. Generally, the Western and the central part of the Catchment area are having flat area with little variation in the altitude, whereas most of the Northern and some parts of South area is highly rugged area which is difficult for agricultural activity.

Table 4.4. Reclassification of elevation of Indris Catchment

Elevation(m)	Ranking	Area in hectare	% of Area	Level of flood hazard
1250-1425	5	35318.44	22.47	Very High
1425-1597	4	32705.44	20.81	High
1597-1822	3	34060.44	21.67	Moderate
1822-1981	2	24156.44	15.37	Low
1981-3156	1	30932.44	19.68	Very low
Total		157173.20	100	

The study area is characterized by five categories of elevation factor (table 4.4). It is evident that the area is largely very low to moderate elevation classes within very low to moderate level of flood hazard together occupy about 57 percent area. It is also noted that about 43 percent area fall under high to very high elevation classes within low to very low level of flood hazard.

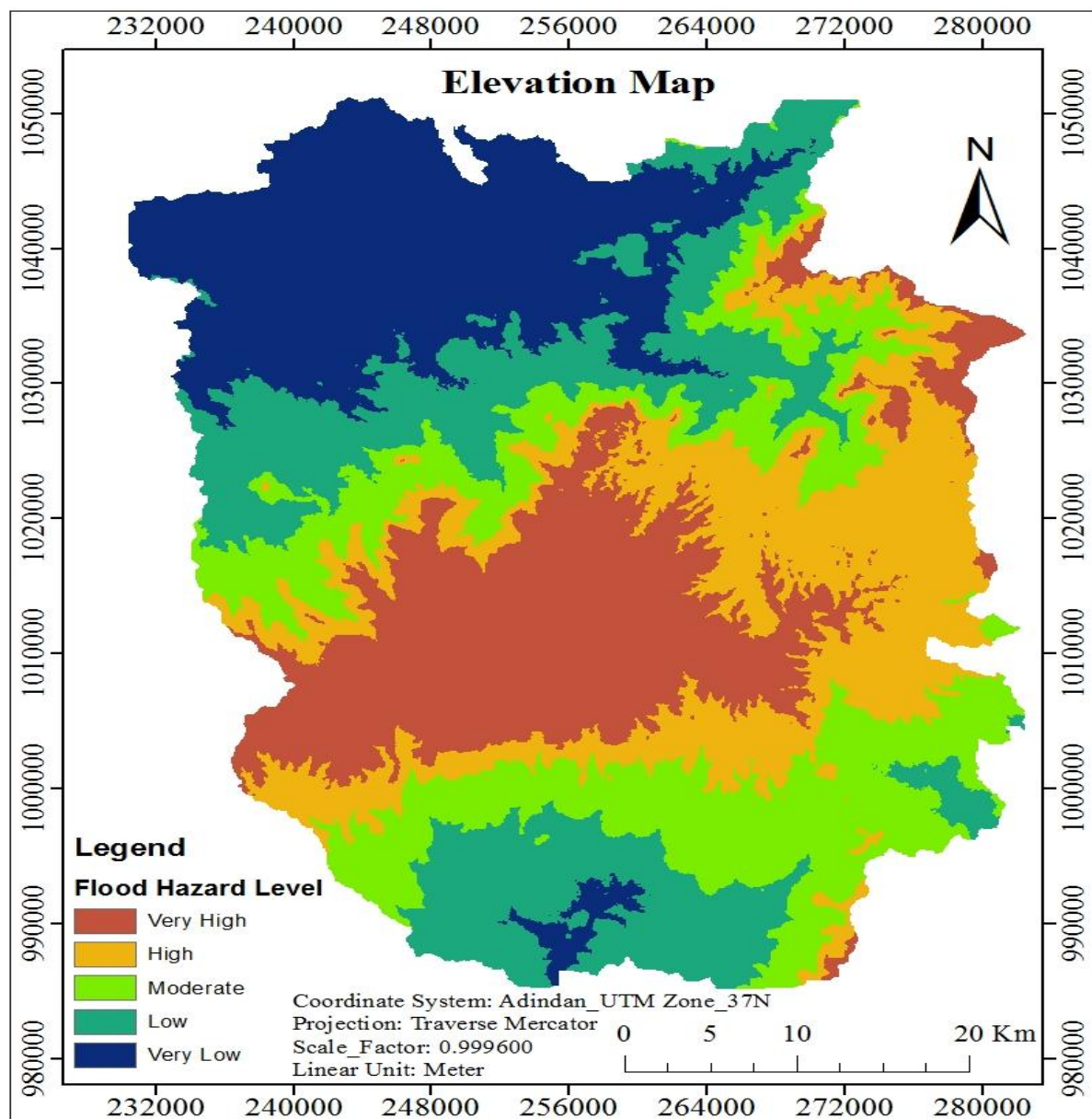


Fig. 4.6. Reclassified elevation map of Catchment

4.4.5. Soil Type

Soil texture and moisture are the most important components and characteristics of soils. Soil textures have a great impact on flooding because sandy soil absorbs water soon and few runoffs occurs. On the other hand, the clay soils are less porous and hold water longer than sandy soils. This implies that areas characterized by clay soils are more affected by flooding. Although there is a wide range of soil types, the soil factor of the Indris Catchment was derived from the

FAO standard classification of Ethiopian soil. These soil types are Pellic Vertisols, Dystric Nitisols, Lithosols, Eutric Nitisols, and Chromic Vertisols. The Dystric Nitisols and Eutric Nitisols are the dominant soil type in the Indris Catchment.

The soil types in an area is important as they control the amount of water that can infiltrate into the ground, and hence the amount of water which becomes flow (Nicholls, 1990). The structure and infiltration capacity of soils will also have an important impact on the efficiency of the soil to act as a sponge and soak up water. Different types of soils have differing capacities. The chance of flood hazard increases with decrease in soil infiltration capacity, which causes increase in surface runoff. When water is supplied at a rate that exceeds the soil's infiltration capacity, it moves down slope as runoff on sloping land, and can lead to flooding (Lowery, 1996).

For this case study, the soil map was classified into five group depend on the basis of infiltration capacity. These, five groups of soil types were converted into raster and reclassified based on the flood generating capacity. The weighted soil map was prepared by assigning weights to each soil classes such that the soil type that has very high capacity to generate very high flood rate is ranked 5 and the one with very low capacity in generating flood rate is ranked 1. From the above soil characteristic which is based on water holding capacity, Chromic Vertisols are assumed to have a very high flooding capacity and ranked as very high class. Eutric Nitisols are assigned as high class, Lithosols are assigned as moderate, Dystric Nitisols are assigned as a low class, and Pellic Vertisols are assumed to have a very low flooding capacity and ranked as very low class (table 4.5).

Table 4.5. Reclassification of Soil type of Catchment

Soil type	Ranking	Area in hectare	% of area	Level of flood hazard
Pellic Vertisols	1	24311.7	15.47	Verv low
Dystric Nitisols	2	40984.2	26.08	Low
Lithosols	3	29158.1	18.55	Moderate
Eutric Nitisols	4	38902.5	24.75	High
Chromic Vertisols	5	23816.70	15.15	Very high
Total		157,173.2	100	

The soil type of the Indris Catchment has five categories. They are Dystric Nitisols which covers a large portion of 26.08 percent of the total area within Low level of flood hazard, Eutric Nitisols which about 24.75 percent within a high level flood hazard, Lithosols which covers 18.55 percent of the total area within Moderate level of flood hazard and Pellic Vertisols and Chromic Vertisols which covers only 15.47 and 15.15 percent respectively.

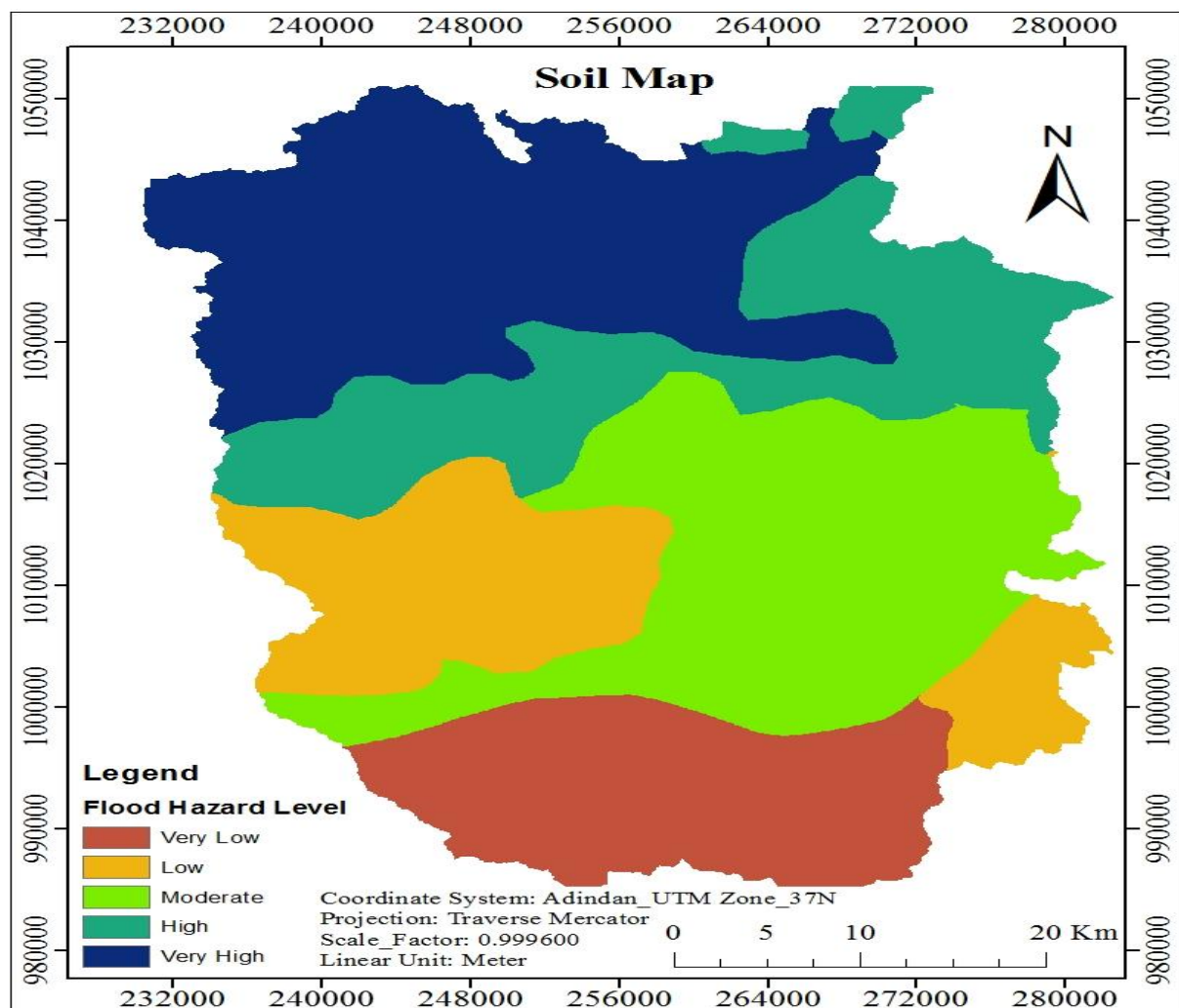


Fig. 4.7. Reclassified soil map of Indris Catchment

4.4.6. Geology

There are five types of geological structure on the Indris Catchment namely; Basalts related to volcanic centers (Colluviums), Post tectonic Granites, Wollega Basalts, Adigrate sandstone and Undifferentiated Lower complex Infra-Adigrates clastics. According, to (Amenti Abraham, 1989), Basalts related to volcanic centers (Colluviums) are medium-textured and

have a good structural stability, a high porosity, a good water holding capacity and good internal drainage. Basalts related to Volcanic centers (Colluviums) have a high proportion of large pores that account for their good aeration, rapid drainage and low moisture holding capacity. Undifferentiated Lower complex Infra-Adigrates clastics have a very low water holding capacity and high permeability.

Therefore, Basalts related to Volcanic centers (Colluviums) are assumed to have a very high flooding capacity and ranked as high class. Wollega basalts are assigned as moderate and Undifferentiated Lower complex Infra-Adigrates clastics are assumed to have a low flooding capacity and ranked as low class. The geology map of the study area (Fig. 4.9.) is clipped from geology map of Ethiopia and converted to raster and then classified for the weighted overlay.

Table 4.6. Reclassification of Geology Indris Catchment

Geology	Ranking	Area in Hectare	% of area	Level of flood Hazard
Basalts related to Volcanic centers (Colvuim)	5	2458.06	1.56	Very high
Posttectonic Granites	4	6200.26	3.94	High
Wollega Basalts	3	83301.46	53.00	Moderate
Adigrate Sandstone	2	27710.26	17.63	Low
Undifferentiated lower complex Infra-Adigrate clastics	1	37503.16	23.86	Very low
Total		157,173.2	100	

The geology type of the Indris Catchment has five categories. They are Undifferentiated lower complex Infra- Adigrate clastics, and Adigrate Sandstone which are covers 42 percent of the total area within ranked as very low and low level of flood hazard, Wollega basalt which covers a large portion of about 53.00 percent within a Moderate level flood hazard, Post tectonic Granites which covers only 3.94 percent of the total area within High low level of flood hazard and Basalts related to Volcanic centers (Colvuim) which covers only 1.56 percent of total area within very high level of flood hazard.

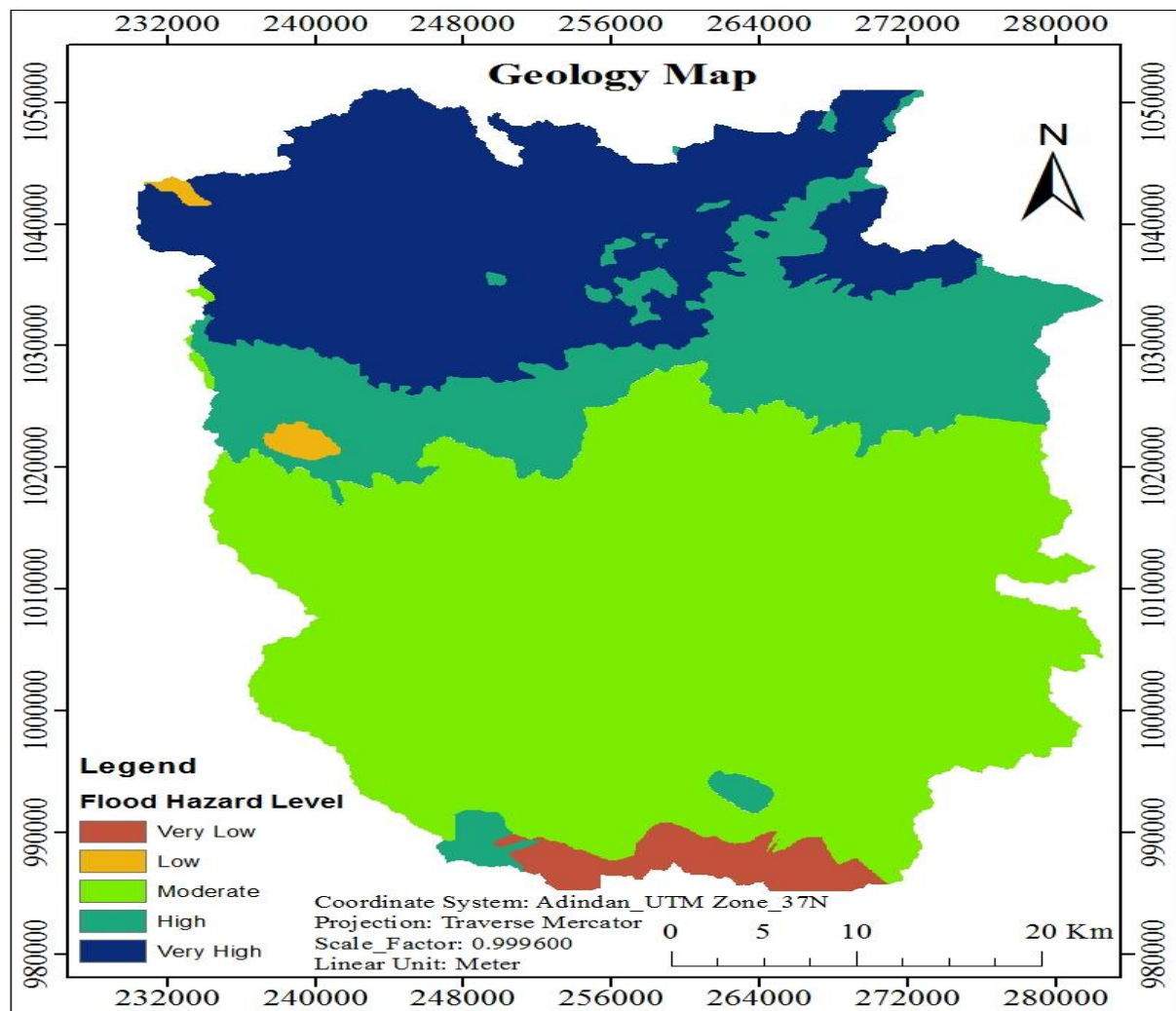


Fig. 4.8. Reclassified geology map of the Catchment

4.4.7. Land Use/Land Cover

The land use/land cover of the area is also one of the primary concerns because this is one factor which not only reflects the current use of the land, pattern and type of its use but also the importance of its use in relation to the living population and its relationship with the existing development.

The vegetation cover of soils, whether that is permanent grassland or the cover of other crops, has an important impact on the ability of the soil to act as a water store. Runoff of rainwater is much more likely on bare fields than those with a good crop cover. The presence of thick vegetative cover slows the journey of water from sky to soil and reduces the amount of runoff. Impermeable surfaces such as concrete, absorbs almost no water at all (Nelson, 2007).

The land use /land cover of the Indris Catchment was acquired on 09/16/2013, having path and row of 169/55. A supervised classification method was adopted using ERDAS Imagine 14 software and later analyzed using Arc-GIS spatial analyst tools as shown in (Fig.4.10). The land use/land cover pattern of the Indris Catchment has been classified into five categories, namely Dense/Sparse vegetation, Scrub/fallow land, Agricultural land, Settlements and Water Bodies. To assess the classification accuracy, confusion matrix was used. The accuracy is essentially a measure of how many ground truth pixels were classified correctly. An overall accuracy of 86.412% was achieved in accuracy assessment. Land use/land cover types were ranked into different categories based on sensitivity to flooding. The higher rank values were assigned to Settlements and water bodies' category and lower values were assigned for dense and sparse vegetation areas.

Table 4.7. Reclassification of Land use/ Land covers of Indris Catchment

Land use/Land Cover	Ranking	Area in (ha)	% of Area	Level of flood hazard
Water bodies	5	4554.4	2.90	Very high
Settlements	4	6365.7	4.05	High
Agricultural Land	3	105745.0	67.28	Moderate
Scrub/Fallow Land	2	15212.7	9.68	Low
Dense/Sparse Vegetation	1	25295.4	16.09	Very low
	Total	157,173.2	100	

Table 4.7. indicated land use/land cover of the Indris Catchment has five classes, namely Dense/Sparse vegetation which covers 16.09 percent of the total area within very low level of flood hazard, Scrub and fallow land which covers about 9.68 percent within a low level flood hazard, Agricultural land which covers a large portion of about 67.28 percent of the total area within moderate level of flood hazard, Settlements and Water Bodies covers only 4.05 and 2.90 percent respectively.

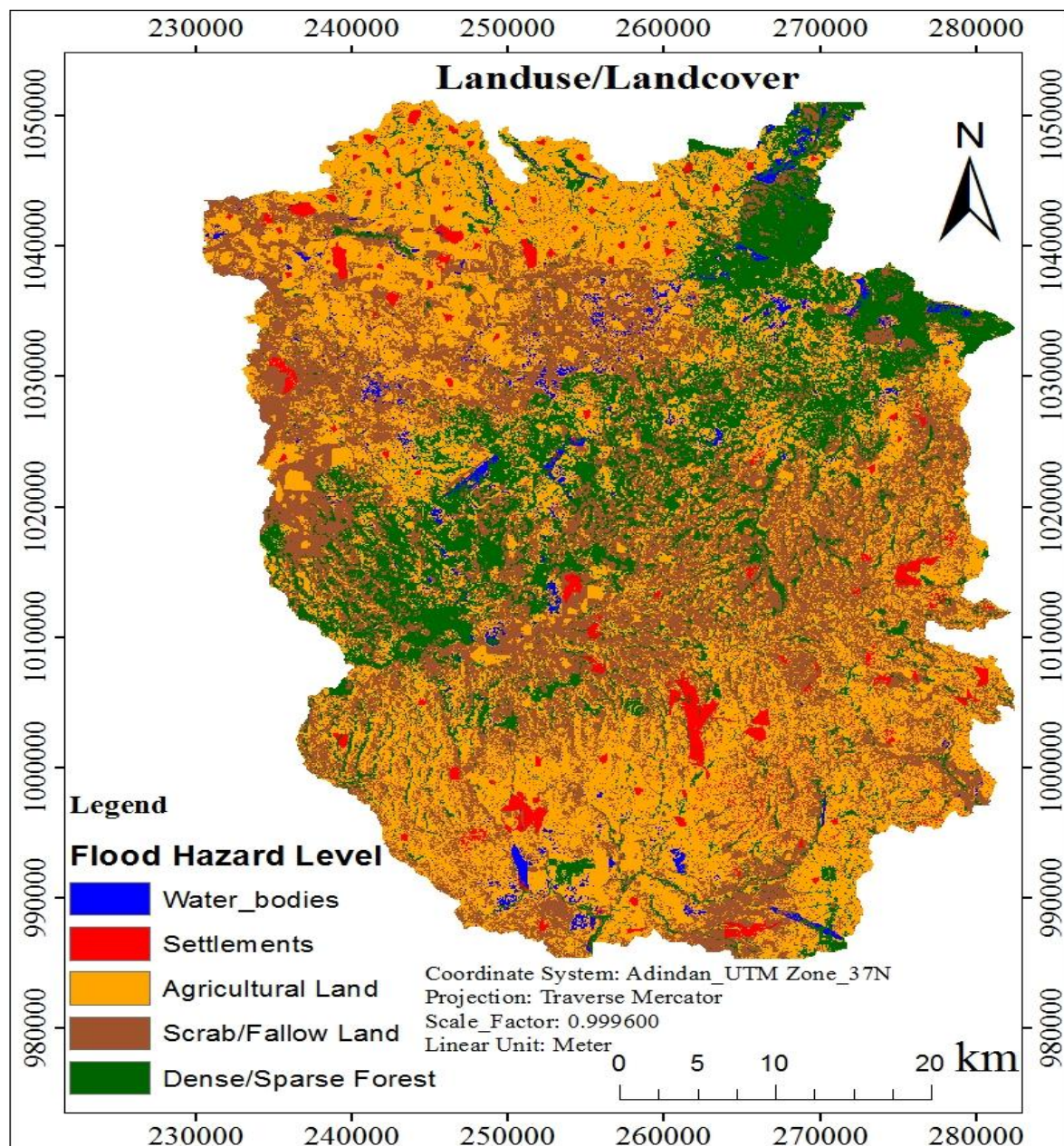


Fig. 4.9. Reclassified LULC map of the Catchment

4.4.8. Population Density

Population data was collected from census of (CSA, 2007). Gross population density calculation method was used to calculate the number of person per square kilometers. Right after updating, population shape file was converted to raster layer using Conversion Tools/ Feature to Raster. Then further the data layer was reclassified in five sub-groups using the

standard classification Scheme. In this classification process an area of high population density is strongly affected by flood and hence ranked to 5, while an area of relatively low population density is the least to be affected by flood and hence ranked to 1 as the results (table 4.8).

Table 4.8. Reclassification of population density Map of Sibu Sire Woreda

Population (No./sq.km)	Ranking	Area in hectare	% of area	Level of flood hazard
0-95.28	1	21622.86	20.62	Very Low
95.28-106.56	2	35845.83	34.19	Low
106.56-213.73	3	23865.58	22.76	Moderate
213.73-391.52	4	16303.86	15.55	High
391.52-2063.53	5	7207.47	6.87	Very high
Total		104845.6	100	

Table 4.8 reveals that the population density value under 0 to 95.28 classes within very low level of flood risk occupies an area 20.08 percent. It is evident that the large portion of area around 35845.83 hectare (34.19 percent) occupied between 95.28 and 106.56 of population density value. At the same time population density value ranged from 106.56 to 213.73 covered an area approximately 21464.86 hectare (22.76 percent). The 15.55 and 6.87 percent area recorded high and very high population density value respectively between 391.52 to 2063.53 classes within high to very high level of flood risk.

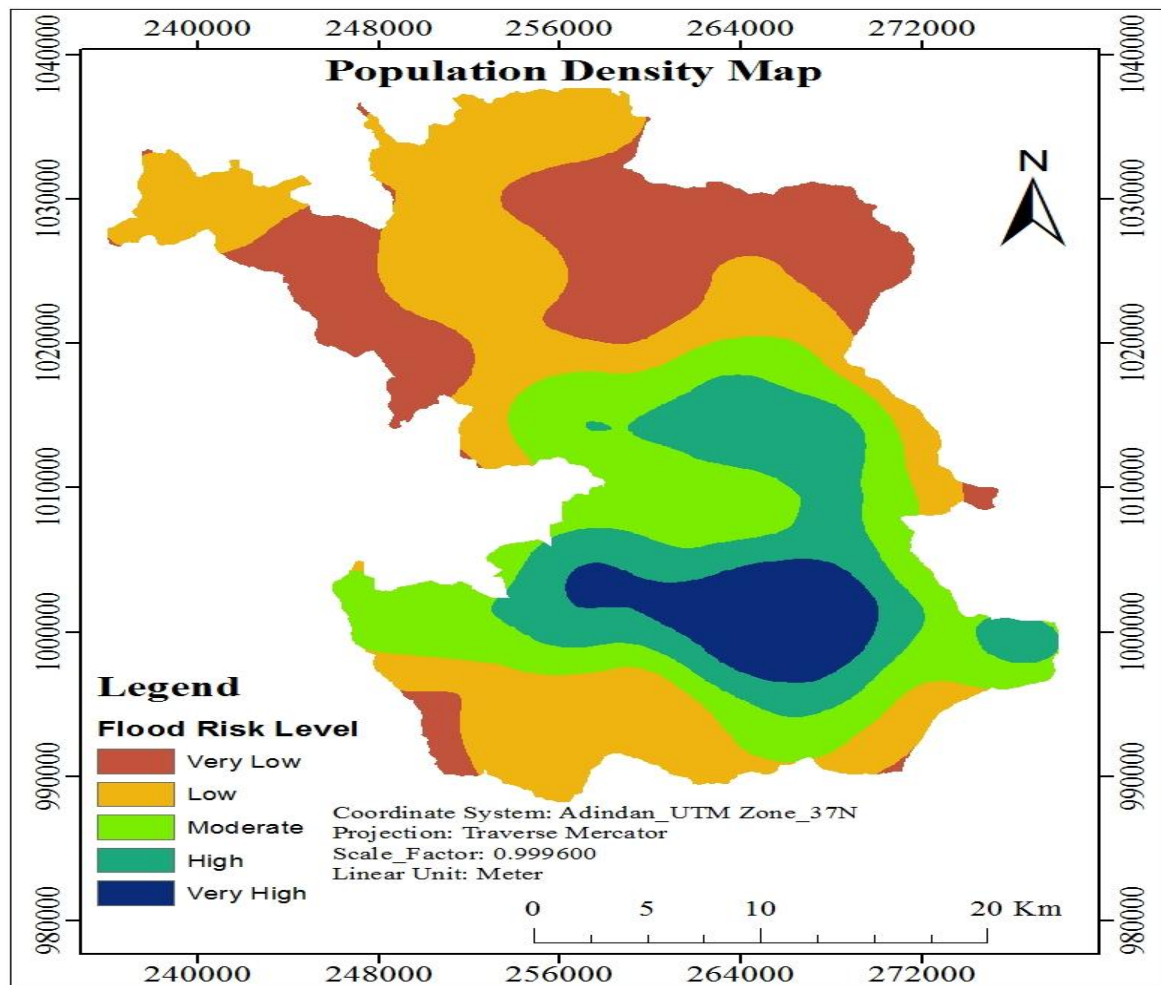


Fig. 4.10. Reclassified population density of Sibu Sire Woreda

4.4.9. Vulnerability

According to (Ken Granger, 2002), the terms vulnerability defined as 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. Vulnerability is a result of excess runoff the Land use / land cover cause in the area. The land use land cover of the study area was extracted from the Catchment land use land cover (fig.4.12). Hence, Vulnerability is one factor that is equally important in weighted overlay process of flood risk with the population density and flood hazard of the study area. The land use/land cover pattern of the Sibu Sire Woreda has five categories, namely such as Dense/Sparse vegetation, Scrub/Fallow land, Agricultural land, Settlements and Water Bodies. Form these land use/land cover classes the dominant one is

Agricultural land. It covers about 34.58% of the total land area as shown in (table 4.9), Land use land cover map of the study area was shown in (Fig.4.12).

Table 4.9. Land use/Land cover of Sibu Sire Woreda

Land use /Land	Area in hectare	Percentage	Level of Vulnerability
Water body	2149.30	2.05	Very high
Settlements	2677.68	2.55	High
Agricultural Land	42364.62	40.41	Moderate
Scrub/Fallow Land	38680.47	36.89	Low
Dense/Sparse	18973.53	18.10	Very low
Total	104845.6	100	

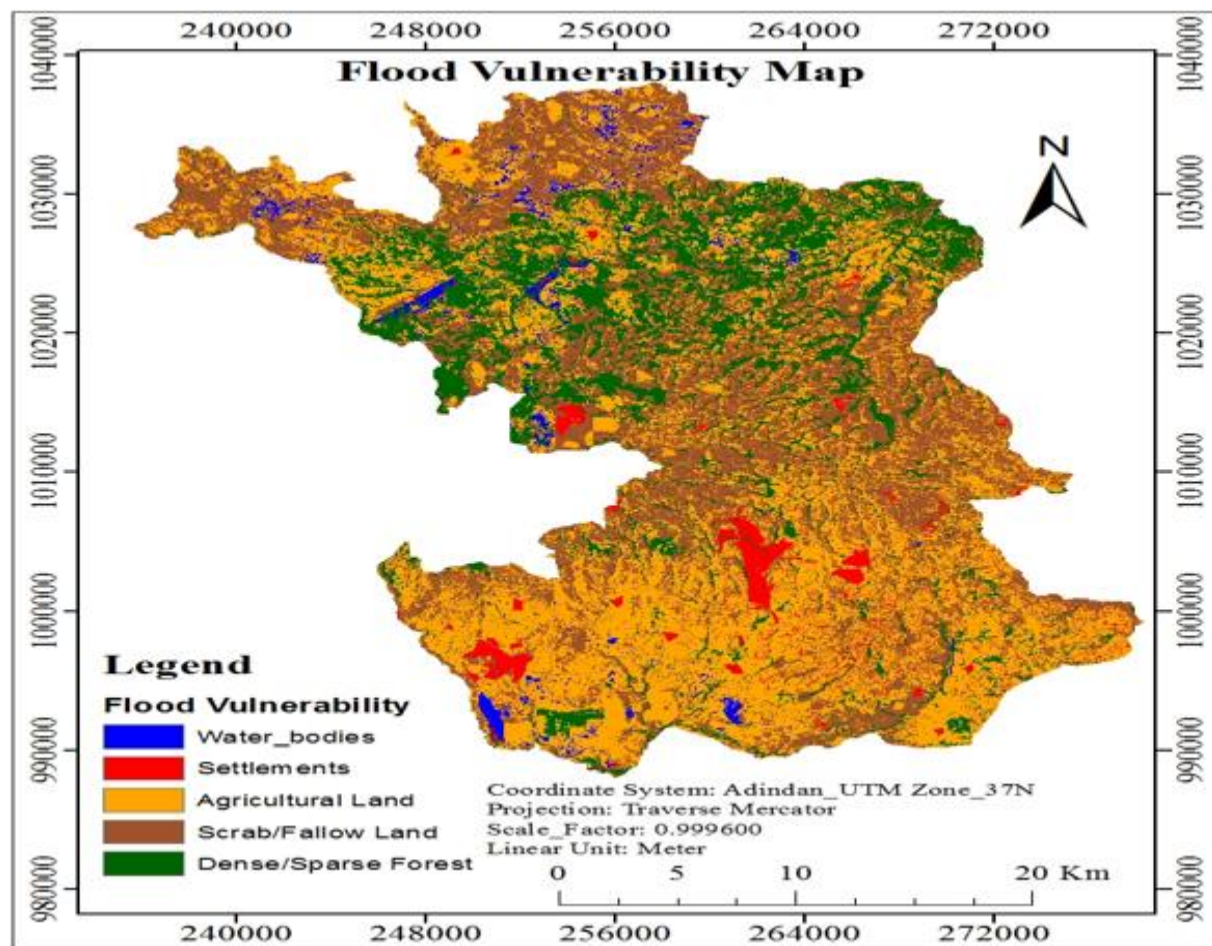


Fig.4.11. Flood Vulnerability Map

4.5. Flood Hazard Analysis

Multi-Criteria Evaluation technique was used to assess flood hazard of the Sibu Sire Catchment using GIS. As explained above in the literature part, MCE is a procedure which needs several criteria to be evaluated to meet a specific objective. It is most commonly achieved by one of two procedures. The first involves Boolean overlay 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) and union (OR).

The second procedure which was used in the study is known as weighted linear combination (WLC) where continuous criteria (factors) were standardized to a common data model that was raster layer with a resolution of 30 m cell size, and then combined by means of a weighted overlay. The result is a continuous mapping of flood hazard and finally threshold to yield a final decision. At this stage, all the factor layers are ready to be combined in order to assess the flood hazard zones in the Catchment. It was done systematically using ArcGIS model builder as shown below in (Fig.4.13).

Table 4.10. The pair comparison matrix of the factors affecting Flood hazard

	Drainage density	Geology	Rainfall intensity	Slope	Soil type	Elevation	LUL C
Drainage density	1						
Geology	1/3	1					
Rainfall intensity	2	5	1				
Slope	1/3	4	1/3	1			
Soil type	1/4	3	1/5	1/2	1		
Elevation	1/5	2	1/4	1/3	2	1	
LULC	1/5	1/2	1/5	1/4	1/3	1/4	1

The computed Eigen vector is used as a coefficient for the respective factor maps to be combined in weighted overlay in Arc-GIS environment.

Table 4.11. The eigenvector of Weights.

The Eigenvector of Weights		Weight (%)
Rainfall	0.332	33.2
Drainage Density	0.2629	26.29
Slope	0.1495	14.95
Elevation	0.0902	9.02
Soil type	0.0787	7.87
Geology	0.0513	5.13
Land use/ Land cover	0.0354	3.54
Total:	1	100
Consistency ratio is 0.06 and consistency is acceptable.		

The consistency ratio (CR) indicates the probability that the matrix ratings were randomly generated so that matrices with CR ratings greater than 0.10 should be re-evaluated. In this study, the critical ratio of the calculated Eigen vector is 0.06, which is acceptable. Therefore, each of the parameters can be assigned by these weights.

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 analysis (table 4.11), whereas in Flood risk assessment all the factors remained to be equally important in Weighted Overlay (table 4.17). The computed Eigen vector was used as a coefficient for the respective factor maps to be combined in weighted Overlay in the Arc GIS environment using the following equation:

$$\text{Flood hazard} = 0.332 \times [\text{Rainfall}] + 0.2629 \times [\text{Drainage Density}] + 0.1495 \times [\text{Slope}] + 0.0902 \times [\text{Elevation}] + 0.0787 \times [\text{Soil type}] + 0.0513 \times [\text{Geology}] + 0.0354 \times [\text{Lu / Lc}] \dots \text{Equation 2.1.}$$

Table 4.12. Weighted flood hazard ranking for Indris Catchment (hazard analysis)

Factors	Weight	Classes	Ranking	Level of Hazard
Rainfall (mm)	0.3320	1456.988-1529.315	1	Very Low
		1529.315-1584.511	2	Low
		1584.511-1647.321	3	Moderate
		1647.321-1729.164	4	High
		1729.164-1940.434	5	Very High

Drainage density(km/Sq .km)	0.2629	0-0.123	5	Very High
		0.123-0.265	4	High
		0.265-0.423	3	Moderate
		0.423-0.665	2	Low
		0.665-1.500	1	Very Low
Slope (Percent)	0.1495	0-7.909	5	Very high
		7.909-15.403	4	High
		15.403-26.643	3	Moderate
		26.643-44.96	2	Low
		>44.96	1	Very low
Elevation (meters)	0.0902	1250-1425	5	Very High
		1425-1597	4	High
		1597-1822	3	Moderate
		1822-1981	2	Low
		1981-3156	1	Very low
Soil type (Related to water absorption)	0.0787	Pellic Vertisols	1	Very Low
		Dystric Nitisols	2	Low
		Lithosols	3	Moderate
		Eutric Nitisols	4	High
		Chromic Vertisols	5	Very High
Geology (Related to drainage capacity)	0.0513	Basalts related to Volcanic centers	1	Very Low
		(Colvuim)	2	Low
		Posttectonic Granites	3	Moderate
		Wollega Basalts	4	High
		Adigrate Sandstone	5	Very High
		Undifferentiated lower complex Infra- Adigrate clastics		

Land use/ Land cover(based on sensitivity to flood)	0.0354	Water bodies	5	Very high
		Settlements	4	High
		Agricultural Land	3	Moderate
		Scrub/Fallow Land	2	Low
		Dense/Sparse Vegetation	1	Very low

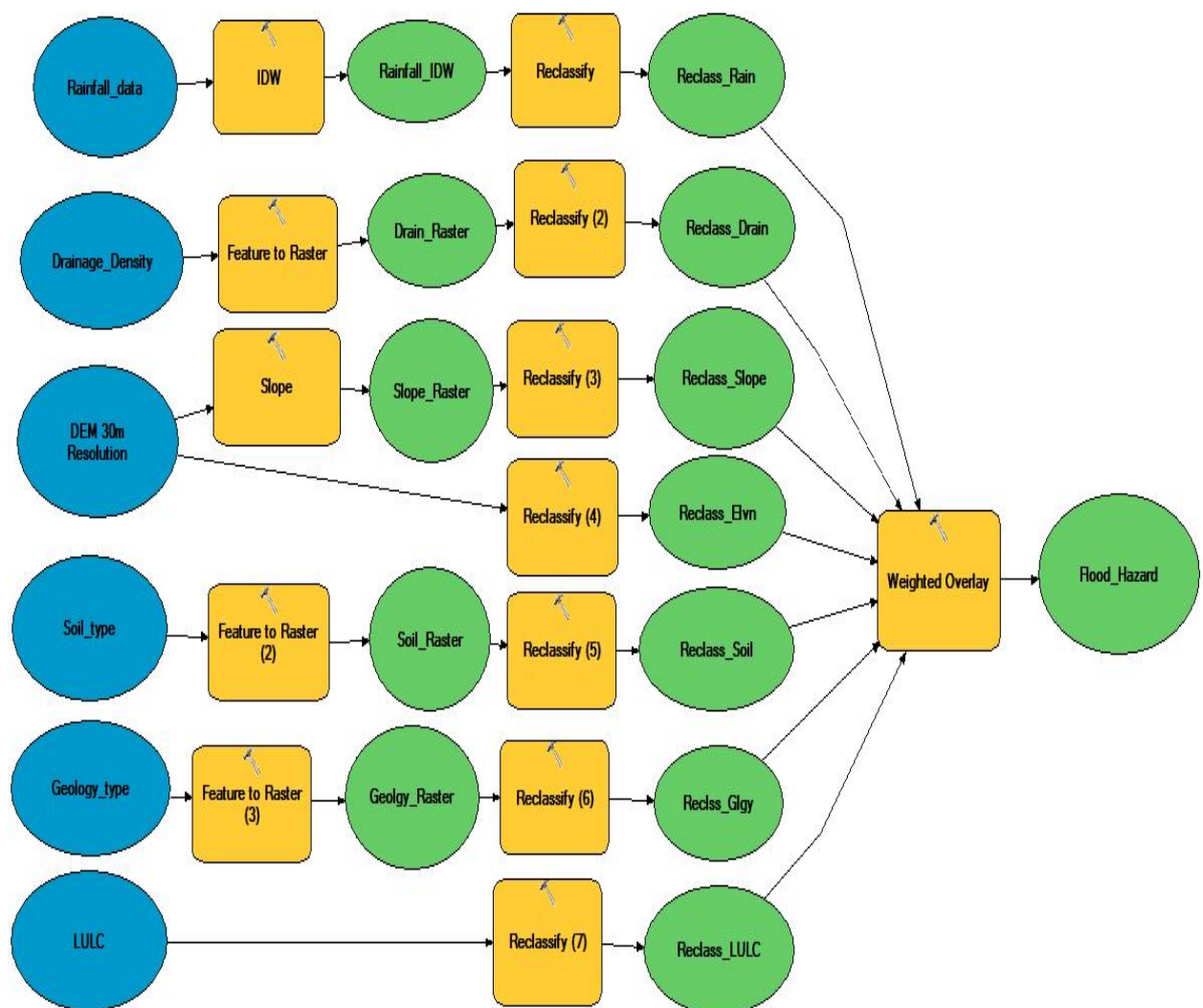


Fig. 4.12.Flood hazard analysis model builder dialogue box

4.6. Flood Risk Analysis

Flood risk of the Woreda was analyzed from the following general risk equation (Shook, 1997).

$$\text{Risk} = (\text{Elements at risk}) * (\text{Hazard} * \text{Vulnerability}).$$

Considering the degree of loss to be total for the study area, the vulnerability is assumed to be one. Elements at risk indicators specify the amount of social, economic or ecological units which are at risk of being affected regarding all kinds of hazards in a specific area e.g. persons, economic production, buildings, public infrastructure, cultural assets, ecological species and landscapes located in a hazardous area on connected to it.

Finally to generate flood risk map of the Woreda, elements at risk layer (population density), vulnerability (land use/land cover) and the flood hazard map of the study area were overlaid using weighted overlay analysis technique in Spatial Analyst tool of Arc-GIS10.1 environment. (Fig. 4.14.), shows the Arc-GIS model builder of the weighted overlay. These three factors remained to be equally important in the Weighted Overlay process (table 4.13.).

Table 4.13. Weighted flood ranking for risk analysis of study area

Factors	Weight	Classes	Ranking
Flood Hazard of Sibu Sire Woreda	0.3333	Very Low	1
		Low	2
		Moderate	3
		High	4
		Very high	5
Population Density (Person/Sq.km)	0.3333	0-95.28	1
		95.28-106.56	2
		106.56-213.73	3
		213.73-391.52	4
		391.52-2063.53	5
Land use/Land cover (based on their Sensitivity to flooding)	0.3333	Dense/Sparse vegetation	1
		Scrub / Fallow Land	2
		Agricultural Land	3
		Settlements	4
		Water Bodies	5

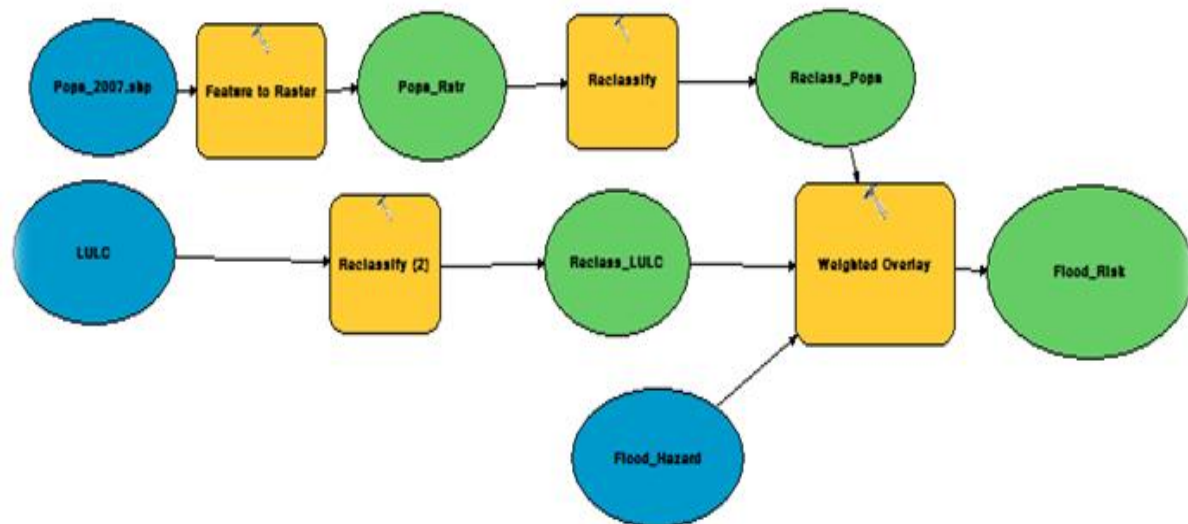


Fig. 4.13. Flood risk analysis model builder dialogue box

4.7. Analysis Existing Awareness level of Society

First of all, undependable answers were eliminated through pre-process and rests of the answers were analyzed statistically using IBM SPSS. Descriptive statistics was used to investigate the difference in total score of knowledge, attitude and practice section toward flood hazard, vulnerability and risk. Above this, relation among knowledge, attitude and practice was investigated through frequency analysis and the results were compared with pre and post flood events.

4.7.1. Awareness

In contemporary research, the term ‘knowledge’ is popularly used in KAP surveys. KAP is a standard term in which the word ‘knowledge’ is implicitly used as a proxy for awareness. To develop the knowledge, Action (performance) and attitude of society to ward any disaster is called awareness. Though, in (fig. 4.15) below awareness is a summation of KAP.

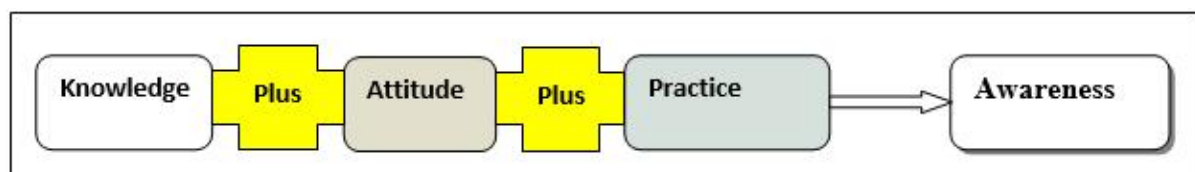


Fig. 4.14. Awareness scheme method

5. RESULT AND DISCUSSIONS

5.1. Flood Hazard Assessment

Determining the flood hazard areas as carried out in this study was important for decision makers for planning and management activities. Traditionally, hydrologic/hydraulic models are commonly used to assess the potential areas of inundation and flood damage for given recurrence intervals. In essence, these models are only based on the balance of the flow and the conveyance of waterways. The flood hazard assessment applied in this study consists of two basic phases: Firstly, the effective factors or variables causing floods are determined. Secondly AHP based MCE in a GIS environment is applied and these approaches are evaluated in finding the flood hazard areas. The results are extended to determine the flood risk map for the different flood hazard zones. Such approach may be more pragmatic than the hydraulic-only models, and integration of the two approaches is recommended.

From the study results, it is observed that AHP offers a flexible, step-by-step and transparent way of analyzing based on experts, end-user preferences, knowledge, and judgments. In fact, the resolution of complex problems in a multi-criteria environment is seen as the primary use of AHP. In this case study where the selected factors such as rainfall, drainage density, slope, elevation, soil type, geology and Land use/land cover data 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 ArcGIS Spatial Analyst tool. If all datasets were equally important, it could be possible to combine them simply. However, from the principal of eigenvector calculation, the relative importance of each parameter was determined. Therefore, the higher the weight, the more influence a particular factor will have in the flood generation.

In this study, the flood hazard maps (Fig 5.1 & 5.2) below shows that the detail results of flood hazard assessment of Indris catchment were 16431.63, 14487.48, 17671.13, 16231.33, 7551.18 hectare and 6542.20, 13256.11, 16369.10, 16000.01, 7322.21 hectare area of Sibu Sire Woreda were subjected respectively, to very low, low, moderate, high and very high flood hazards as shown in (table 5.1) and (table 5.2).

Table 5.1. Areas coverage of Flood hazard analysis of Indris Catchment.

Class	Area in hectare	% of total area	Level of hazard
1	24809.28	15.78	Very low
2	41333.94	26.30	Low
3	65348.12	41.58	Moderate
4	10514.91	6.69	High
5	15166.95	9.65	Very high
Total	157173.2	100	

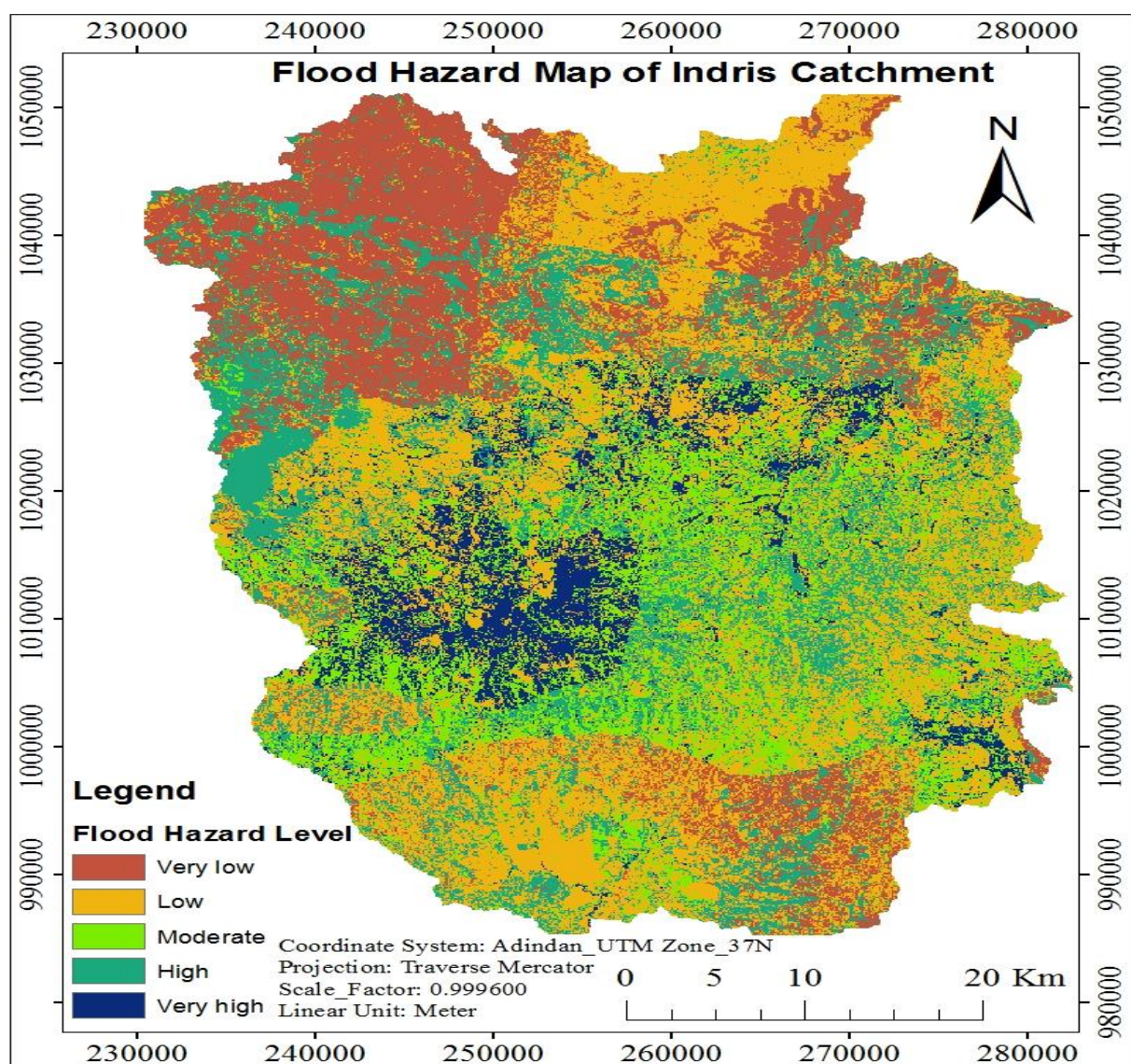


Fig. 5.1. Flood hazard map of Indris Catchment.

Hence, for further information the flood hazard detail analyzed of Sibu Sire Woreda were assessed as per existing Kebele and Land use / Land cover using the area tabulation of spatial analyst in Arc-GIS environment. (Fig.5.2), shows the study area flood hazard map as per the existing Woreda Kebele boundary. Area tabulation was done in spatial analyst tool using Arc GIS software and the result was summarized as area tabulation of flood hazard versus land use/land cover (table 5.3), and flood hazard versus kebele boundary, (table 5.4).

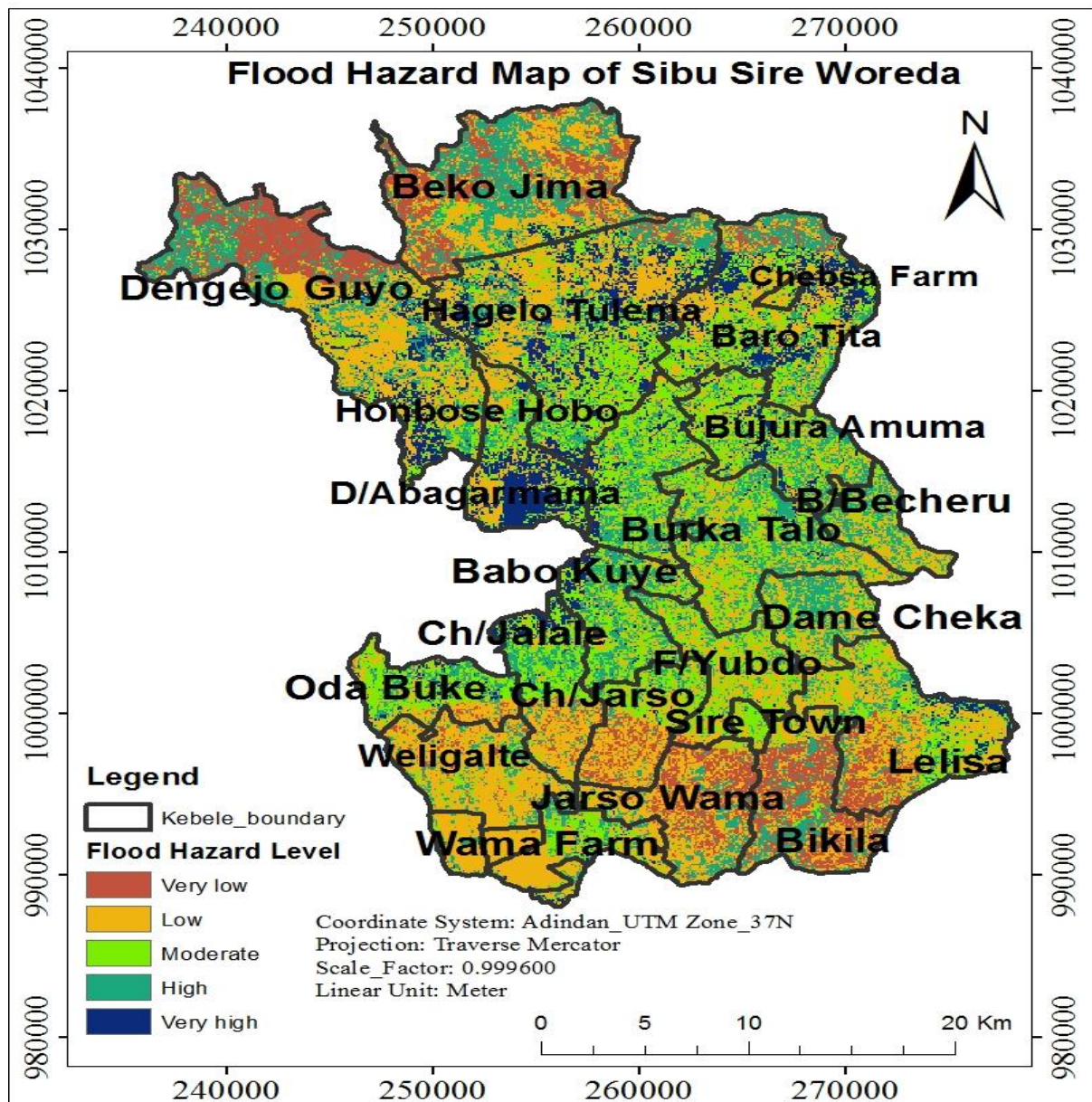


Fig. 5.2. Flood hazard map of Sibu Sire Woreda

From the flood hazard map (Fig 5.2), it was estimated that 11074.6, 39791.3, 19679.67, 23818.41 and 10481.7ha of the area considered in Sibu Sire Woreda were subjected respectively, to very low, low, moderate, high and very high flood hazards (table 5.3). Further analysis revealed that Water body (95.7%), Settlement (82.9%), Agricultural land (74.8%), Scrub/Fallow land (54.0%), Dense/Sparse vegetation (55.1%) faces low to moderate flood hazard. Besides (17.1%) of the settlement and (25.2 %) agricultural areas is categorized into high to very high hazard (table 5.2).

Table 5.2. Area tabulation of Flood hazard map versus Land use / Land Cover of Sibu Sire Woreda

Land use land cover type	Flood Hazard					Total
	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)	
	Area(ha)					
Water body	455.85	1546.92	48.06	67.95	23.67	2142.45
Settlement	263.34	1215.99	521.64	478.08	195.21	2674.26
Agricultural land	6510.25	20610.2	8126.46	5794.29	1490.76	42531.94
Scrub/Fallow land	3263.31	9849.87	7704.36	14729.67	3017.16	38564.37
Dense/Sparse vegetation	581.85	6568.29	3279.15	2748.42	5754.87	18932.58
Total	11074.6	39791.3	19679.67	23818.41	10481.7	104845.6

Kebeles were also evaluated in terms of flood hazard level as it is an important domain to administer the population in the Woreda (fig.5.2). Accordingly, kebele Burka Talo , Bujura Amuma , Cheri jarso, Chafe Jalale, Hagelo Tulema, Oda Buke and Jarso Waama are respectively, 53.1%, 33.3%, 39.7%, 44.6%, 23.6%, and 38% of the total area under consideration are subjected to high to very high flood hazard (table 5.3). Hence these kebeles needs immediate attention for alleviating future potential flood hazard.

Table 5.3. Area tabulation of Flood hazard map versus existing Kebele boundary of Sibu Sire Woreda

Kebele Name		Flood Hazard					Total
		Very low (1)	Low (2)	Moderate (3)	High (4)	Very high (5)	
		Area in Hectare					
1	Sire Town	3	162.81	2.07	257.64	0	425.52
2	D/GUYO	6.48	360.07	1878.29	6382.82	3006.11	11633.77
3	BEKO_JIMMA	0	899.67	574.14	2555.81	5161.76	9191.38
4	H/TULEMA	91.54	117.36	2600.69	8622.03	486.07	11917.69
5	HONBOSE HOBO	76.9	12.39	2847.44	888.02	2.44	3827.19
6	D/ABAGERMAM	291.81	222.05	2205.13	1598.59	0	4317.58
7	BARO TITITA	47.79	407.39	491.8	6946.45	295.76	8189.19
8	B/AMUMA	141.59	872.06	461.76	2952.5	0	4427.91
9	B/BECHERO	115.67	572.64	194.26	1147.16	0	2029.73
10	BURKATALO	655.74	853.47	1583.66	2728.01	0	5820.88
11	DAME CHEKA	125.91	497.53	433.59	1492.87	0	2549.9
12	F/YUBDO	181.77	1215.8	338.29	1715.11	0	3450.97
13	CHERI JARSO	15.59	1208	37.65	1892.19	25.54	3178.97
14	BABO KUWE	297.92	234.73	1790.88	1254.86	0	3578.39
15	CH/JALALE	55.21	400.35	1166.32	1954.44	59.9	3636.22
16	ODA BUKE	25.35	383.17	693.29	1825.06	0	2926.87
17	JARSO WAMA	0	1531.74	92.48	2129.73	523.35	4277.3
18	BIKILA	1.88	1944.49	89.2	2487.27	124.41	4647.25
19	LELISA	28.07	2259.3	198.16	3911.32	164.78	6561.63
20	WELI GELTE	0.56	997.22	123.56	3328.35	3807.57	8257.26
	Total	2162.78	15152.24	17802.66	56070.23	13657.69	104845.6

5.2. Flood vulnerable Assessment

Vulnerability is directly related to the degree of exposure and inversely related to the capacity to cope and recover or adapt (Finan et al, 2002). Therefore, not only is it important to identify high risk areas, it is critical to identify vulnerable populations, understand what causes people to be vulnerable, and assess the measures that can reduce vulnerability (Blaikie, 1994). The result is a flood vulnerability or hazard map showing the most vulnerable areas to flooding within the study area. The results of this stage of analysis are shown in (Fig.5.2). As depicted in (table 5.2) above, the results show that almost a 15.2% of the total Sibu Sire Woreda was prone to “high” and or “very high” flood hazards. These areas are those that are close to the rivers and generally laying at low elevations within the settled/paved regions. Conversely, 84.8% of the study area was prone to “very low” to “moderate” level of flood hazards. Most of these areas tended to be on the higher grounds and further away from the high drainage density areas.

Significantly, the results in (table 5.3) reveals the fact that Sibu Sire Woreda some kebeles were prone to “moderate” flooding vulnerability. This is due to the fact that despite the settlement area having drainage networks, most of them are blocked and joined with the settled surfaces hinder water infiltration of runoff, these areas are prone to flooding events during heavy rainfall occurrences.

5.3. Flood Risk Assessment

Flood risk mapping and assessment was done for Sibu Sire Woreda by taking population and land use/land cover elements that are at risk combined with the degree of flood hazards of the Woreda. According to the flood risk map, it was estimated that 2586.61, 46216.26, 26561.61, 27448.2 and 2032.92 hectares areas of Sibu Sire Woreda were subjected respectively to very high, high, moderate, low, and very low flood risk as revealed in (fig.5.3).

Elements at risk considered in this study show different levels of risk. The Woreda Kebele that are about large hectare their area under high to very high flood risk include Eastern part kebele Baro Tita (3206.34 hectare), B/Amuma (1452.15 hectare), Northern part Boko Jima(3312.99 hectare), Hagelo Tulema (4647.24 hectare), Centre part Burka Talo (1363.32 hectare), Sourthern part Jarso wama(1315.89 hectare), Weli-galte (818.64 hectare) and

Western part Jafe Jalale(1153.26 hectare),Oda Buke(826.74 hectare), Dengejo Guyo (3943.8) detail in (table 5.5.) With regard to the other element at risk, land use/land cover, 89.1 hectare water body, 520.56 hectare Settlement, 5898.24 hectare agricultural lands, 14688.18 hectare Scrub/Fallow land, 8285.31 hectare Dense/Sparse vegetation were under high to very high flood risk (table 5.4).

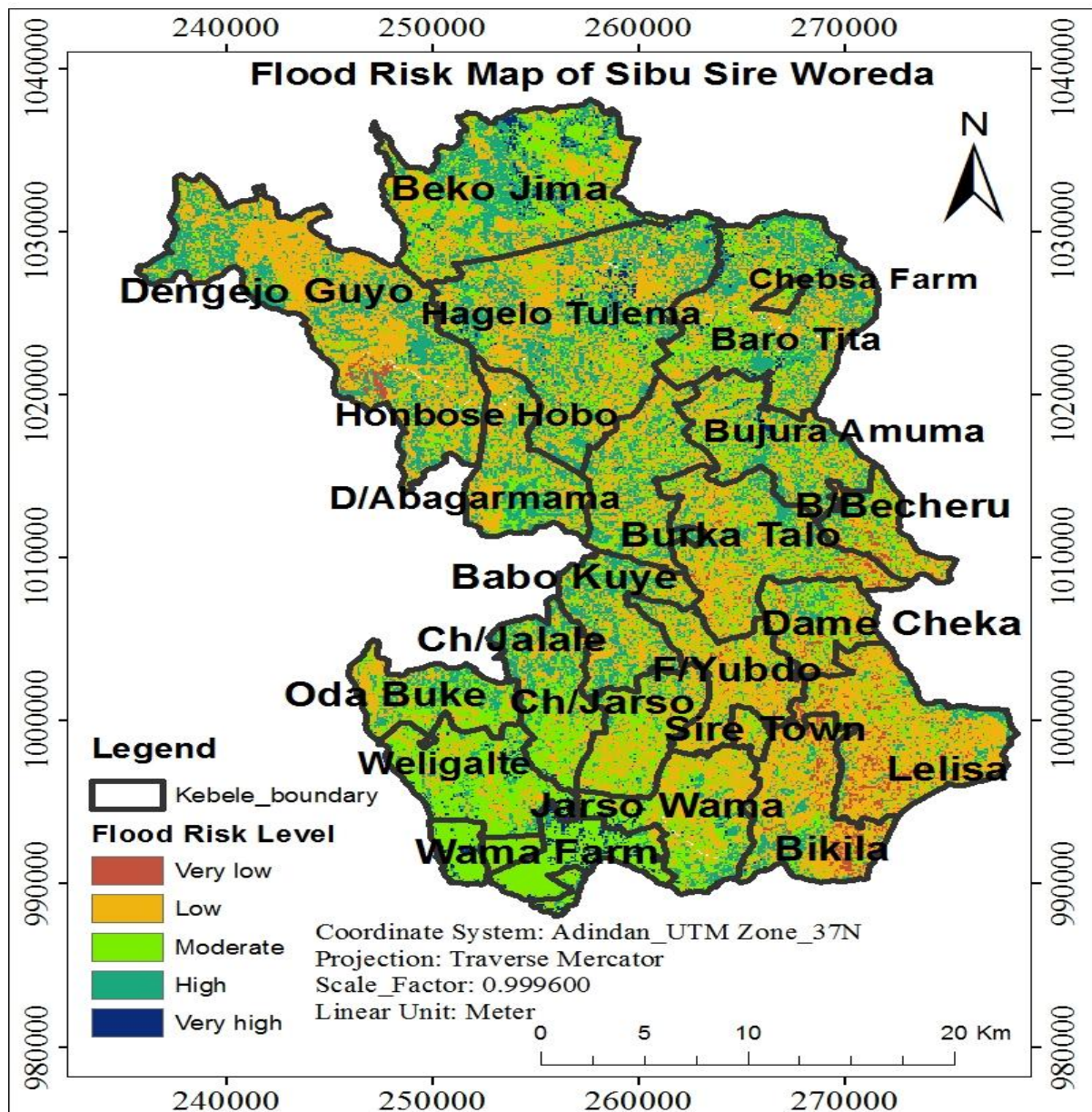


Fig. 5.3. Flood risk map of Sibu Sire Woreda

Flood risk map of the Woreda was assessed to per Land use/land cover of the area (fig. 5.3), it was estimated that 2585.8, 46216.44, 26561.97, 27448.2 and 2033.19 ha of the area considered in Sibu Sire Woreda were subjected respectively, to very low, low, moderate, high and very high to flood risk (table 5.4). Further analysis revealed that (4.2%) water body, Settlement (19.5%), agricultural land (13.8%), Scrub/Fallow land (38.1%) and Dense/Sparse vegetation (43.8%) areas of the study area faces high to very high flood risk level (table 5.4).

Table 5.4. Area coverage of Flood risk versus Land use/Land Cover of Sibu Sire Woreda

Land use land cover type	Flood Risk					Total
	Very Low	Low (2)	Moderate (3)	High (4)	Very High (5)	
	Area(ha)					
Water body	35.55	1280.25	730.62	78.66	10.44	2135.52
Settlement	83.43	1334.16	735.39	502.92	17.64	2673.54
Agricultural land	1726.93	22288.59	12676.68	5497.65	400.59	42590.44
Scrub/Fallow land	532.35	13764.6	9557.37	13944.5	743.67	38542.5
Dense/Sparse vegetation	207.54	7548.84	2861.91	7424.46	860.85	18903.6
Total	2585.8	46216.44	26561.97	27448.2	2033.19	104845.6

Flood risk level were also evaluated as per the 20 Kebeles of the Sibu Sire Woreda, it is an important domain to administer the population in the Woreda. Accordingly, kebele Beko Jimaa, H/Tulema, H/Hobo, D/A/Germama, Baro Titita, and Babo Kuwe are respectively 36.2%, 39.0%, 33.6%, 34.8%, 39.2% and 38.7% of the total area under consideration are subject to high to very high flood risk. Hence these kebeles needs immediate attention for alleviating potential future flood risk (table 5.5).

Table 5.5. Area tabulation of Flood Risk map versus existing Kebele boundary of Sibu Sire Woreda

Kebele Name		Flood Risk					Total
		Very low (1)	Low (2)	Moderate (3)	High (4)	Very high (5)	
		Area in Hectare					
1	Sire Town	7.56	255.24	127.35	35.19	0	425.34
2	Dengejo Guyo	179.1	6407.01	1035.45	3905.3	38.43	11565.36
3	Beko Jimma	0	3276.9	2560.86	2884.0	428.94	9150.75
4	H/Tulema	0	5362.38	1909.35	4291.1	356.13	11918.97
5	H/Hobo	0	1796.22	733.5	1277.8	4.86	3812.4
6	D/A/Germama	0	1926.72	890.55	1475.1	25.92	4318.38
7	Baro Titita	0	3251.7	1716.03	2902.3	304.02	8174.07
8	B/Amuma	29.16	1956.24	984.96	1373.9	78.21	4422.51
9	B/ Bechero	220.95	866.25	528.48	403.74	0	2019.42
10	Burka Talo	257.49	2925.9	1271.97	1361.4	1.89	5818.68
11	Dame Cheka	223.65	1130.94	737.73	454.41	0	2546.73
12	Felamo Yubdo	99.27	2201.31	660.51	482.13	5.13	3448.35
13	Cheri Jarso	0	1473.66	1250.55	436.32	20.34	3180.87
14	Babo Kuwe	2.79	1501.56	687.06	1379.0	5.13	3575.61
15	Chefe Jalale	0	1093.77	1376.73	1131.9	21.33	3623.76
16	Oda Buke	0	987.93	1096.56	816.57	10.17	2911.23
17	Weli Gelte	0	963.27	2748.33	604.8	213.84	4530.24
18	Jarso Wama	360.64	2039.58	4614.75	803.52	512.37	8330.86
19	Bikila	518.49	2690.91	681.03	738	6.21	4634.64
20	Lelisa	687.51	4108.77	949.86	691.29	0	6437.43
	Total	2586.61	46216.26	26561.61	27448.	2032.92	104845.6

According to the flood risk map (Fig. 5.3), it was estimated that 7925.074, 35436.42, 51886.28, 8493.961, and 2003.864 hectare areas of Sibu Sire Woreda were subjected respectively to very high, high, moderate, low, and very low flood risk. Finally, the results of interpretation and analysis show that areas about 2.11 percent of the total area of Sibu Sire Woreda is falls under very high flood risk zone. Of the total study area, about 23.11 percent falls under the category of moderate flood risk potential; while the area covered under the very low and low flood risk zone category, which occupied approximately 69% area of the Sibu Sire Woreda. Since 9.88%

of the Woreda is under high and very high (extreme) flood risk, adoption of suitable conservation measures seems to be inevitable.

5.4. Existing Awareness Level Assessment

(Palp & Werner, 2006), defines risk awareness as an everyday subjective assessment process that is based on experience and on available information without referring to reliable data, series and complex models. The existing awareness level analysis of society was important for mitigation plan. Considering the degree level of awareness of loss to be total for the study area, the flood hazard, vulnerability and risk were assessed through the KAP using the SPSS software pre and post flood event.

5.4.1. Knowledge of flood Hazard before and after flood

Knowledge of society towards the flood hazard and risk was collected from respondents of study area society. Table 5.8. depicted the result of knowledge of respondents to the flood hazard from the descriptive frequency analysis of the SPSS before the event happen as 20%, 42.5%, 30%, 7.5% and 0% to the rank of very low(1),low(2),moderate(3),high(4) and very high(5) respectively.

Table 5.6. Knowledge of flood hazard before the flood.

Weight (Rank)	Frequency	Percent	Valid Percent	Knowledge of flood hazard
1	8	20.0	20.0	Very low
2	17	42.5	42.5	Low
3	12	30.0	30.0	Moderate
4	3	7.5	7.5	High
5	0	0	0	Very high
Total	40	100.0	100.0	

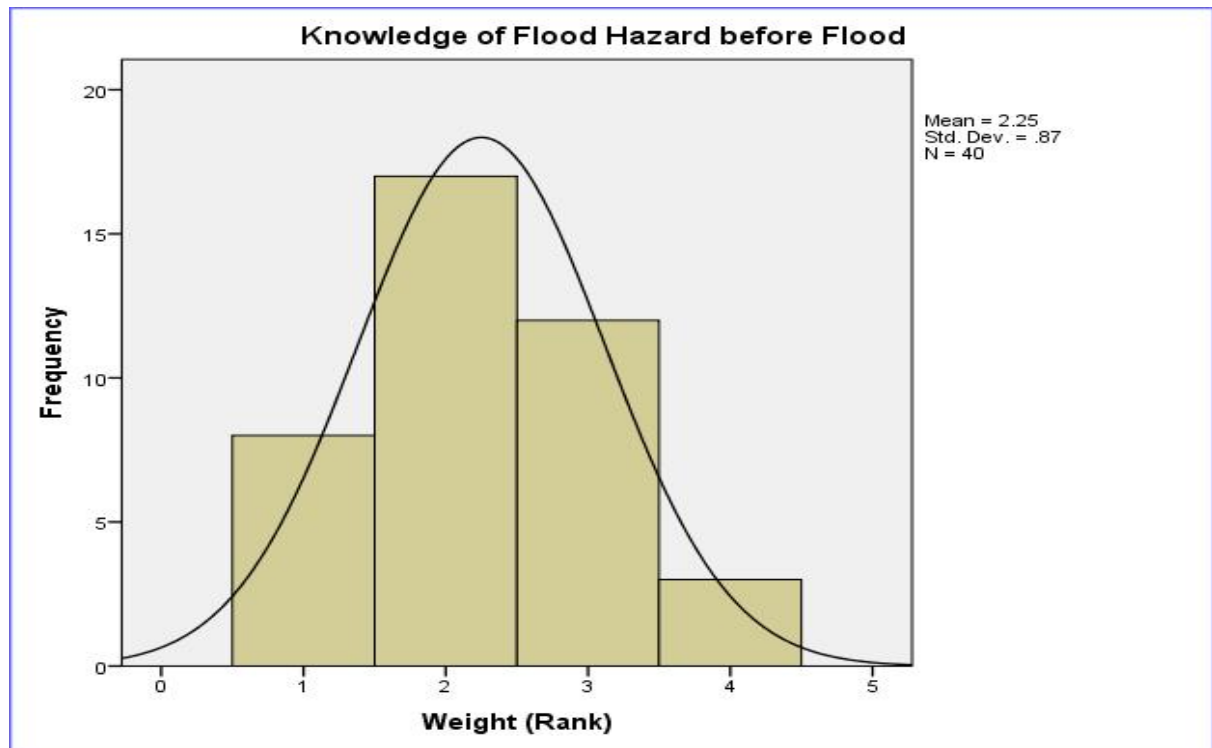


Fig. 5.4. Graph for knowledge of flood hazard before flood

The knowledge of people about flood hazard was increase after the events happen, was 32.5% was moderate and more than 67.5% were high and very high in (table 5.7.), and also (fig. 5.5), show the histogram graph of knowledge after the event.

Table 5.7. Knowledge of flood hazard after flood event.

Weight (Rank)	Frequency	Percent	Valid Percent	Knowledge of flood hazard
1	1	2.5	2.5	Very low
2	1	2.5	2.5	Low
3	11	27.5	27.5	Moderate
4	13	32.5	32.5	High
5	14	35.0	35.0	Very high
Total	40	100.0	100.0	

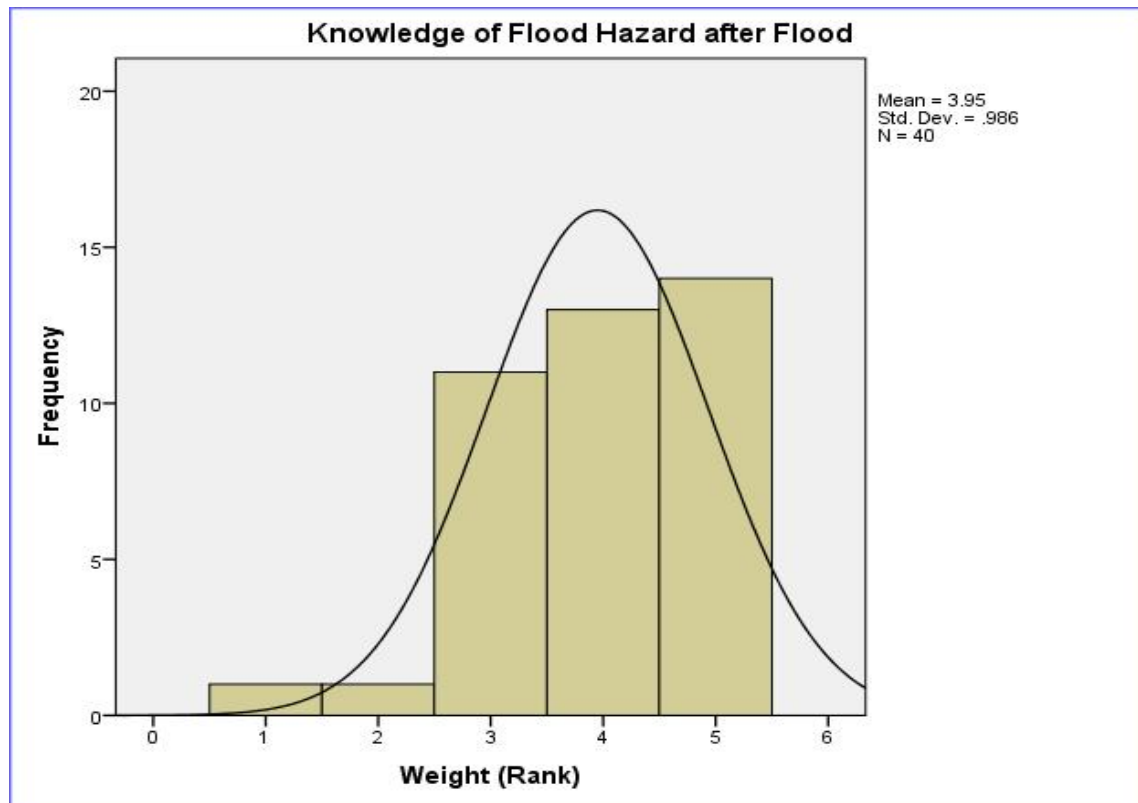


Fig. 5.5. Graph for knowledge of flood hazard after flood

5.4.2. Knowledge of flood vulnerability before and after flood

Vulnerability can be reduced by identifying, helping, and empowering those who are most vulnerable (Hewitt, 1997). In the hazards and disaster field, there was growing recognition that there was a need to reorient emergency management systems to be more proactive in reducing losses (life and property) and future hazard impacts through mitigation, preparedness, response, and recovery rather than focusing on rescue and post-event clean-up. This was based on the growing recognition that the degree to which populations are vulnerable to hazards is not merely dependent on the exposure to the hazard proximity to the source of the threat or the physical nature of the hazard, but it is also socially constructed and based on social, economic, and political factors that have a role in defining vulnerability.

Some population subgroups because of disparities in wealth, socioeconomic status, and housing have an increased potential for losses due to hazards as they have less ability to adapt cope or respond. Access to resources, be they economic, social, or political, are fundamental to the adaptation process and differential access to resources to mobilize to adapt influences vulnerability of households, individuals, and communities. Adaptation relies on human and

financial capital (knowledge and money) and changes and readjustments in social organization (investments in social and political capital) to reduce vulnerability (Blaikie, 1994).

Knowledge of the flood vulnerability before and after events of flood can analyses by the descriptive analysis of the SPSS software. During data collection knowledge of the respondents to the vulnerable, is very highly and then ranked as class 5, whereas, the answer of the respondent very low or almost not know the vulnerable of flood was ranked as 1, (table 5.8.) and (fig.5.6.) shows the result detail.

Table 5.7. Knowledge of flood vulnerability before flood.

Weight (Rank)	Frequency	Percent (%)	Valid Percent (%)	Knowledge of vulnerability
1	5	12.5	12.5	Very low
2	18	45.0	45.0	Low
3	15	37.5	37.5	Moderate
4	2	5.0	5.0	High
5	0	0	0	Very high
Total	40	100.0	100.0	

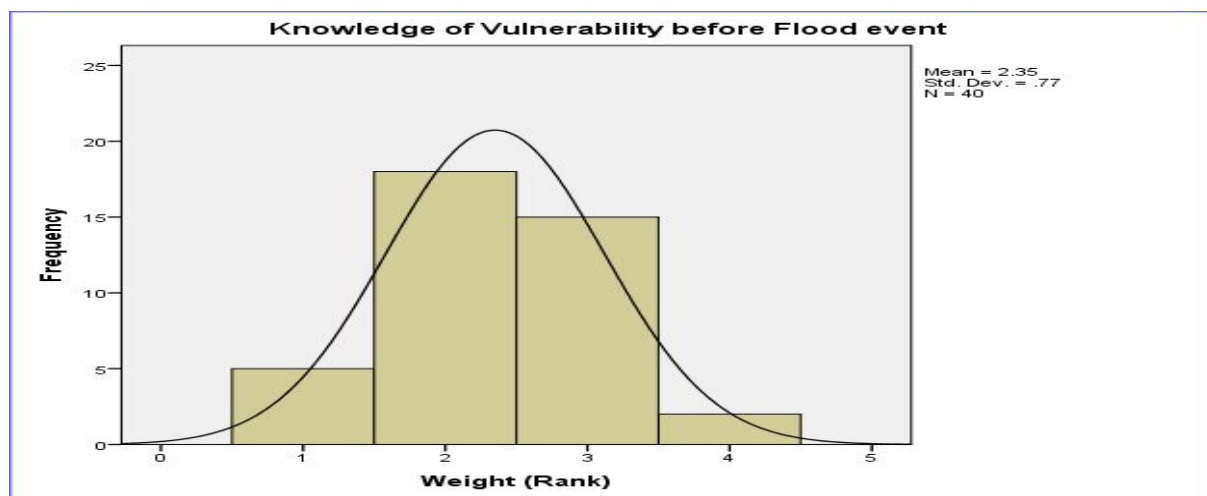


Fig. 5.6. Graph for knowledge of vulnerability before flood

According to descriptive frequency analysis of SPSS software the knowledge of respondents to flood vulnerability after the events was increase from 0% for very low(1) to 35% for very high (5) (table 5.9.). (Fig. 4.7.), shows the graph of respondents' knowledge to flood vulnerability was increases after the events happen than before. General, the preparedness of

population of Sibu Sire Woreda to flood vulnerability was very low before the events and increased after the events.

Table 5.8. Existing knowledge of flood vulnerability after flood

Weight (Rank)	Frequency	Percent	Valid Percent	Knowledge of vulnerability
1	0	0	0	Very low
2	1	2.5	2.5	Low
3	11	27.5	27.5	Moderate
4	14	35.0	35.0	High
5	14	35.0	35.0	Very high
Total	40	100.0	100.0	

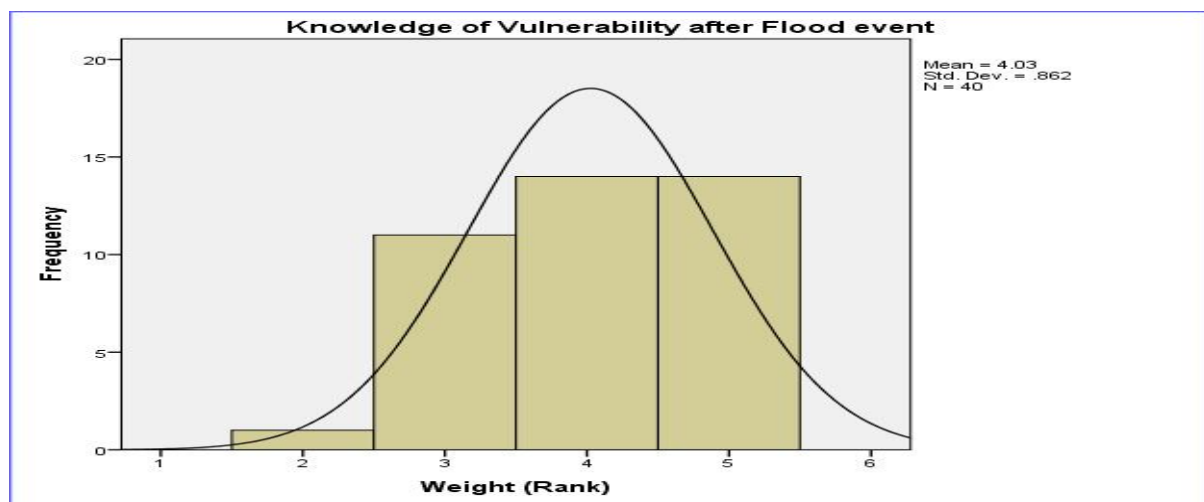


Fig. 5.7. Graph for knowledge of vulnerability after flood

5.4.3. Knowledge of flood Risk before and after flood events

Risk (R) is defined as expected degree of loss due to a particular natural phenomenon (Shook, G., 1997). So, knowledge of the people about the natural phenomenon is very important and it used save a life and property. In this study, it is necessary to analysis the awareness level of population to the flood risk for the mitigation measurement due the particular phenomenon. The descriptive frequency analysis of SPSS value of data collected knowledge of flood risk before the flood events from the sample respondents who are represents the whole population of the Woreda. Knowledge of flood risk before flood events was 25%-30% for very low to low whereas, 0% for very high rank (5) or almost the society not understand the flood risk (table 5.12), and (fig.5.8), shows the histogram graph of the analysis result.

Table 5.9. Knowledge of flood risk before flood

Weight (Rank)	Frequency	Percent	Valid Percent	Knowledge to flood risk
1	10	25.0	25.0	Very low
2	12	30.0	30.0	Low
3	15	37.5	37.5	Moderate
4	3	7.5	7.5	High
5	0	0	0	Very high
Total	40	100.0	100.0	

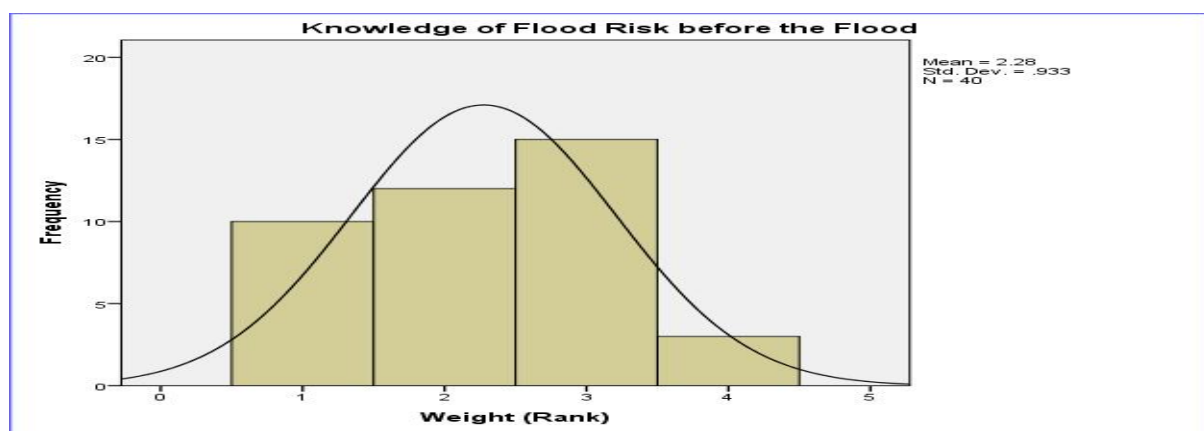


Fig. 5.8. Graph for knowledge of flood risk before flood

(Table.5.11), show that, the Knowledge of flood risk after the events happen was increase from 7.5 % to 22.5% for high rank, and from 0% to 7.5% for very high rank, means that the preparedness of society toward the risk was increase after event. The SPSS analysis result was depicted in (fig.5.9).

Table 5.10. Existing knowledge of flood risk after flood happen

Weight (Rank)	Frequency	Percent	Valid Percent	Knowledge to flood risk
1	0	0	0	Very low
2	4	10.0	10.0	Low
3	11	27.5	27.5	Moderate
4	9	22.5	22.5	High
5	16	40.0	40.0	Very high
Total	40	100.0	100.0	

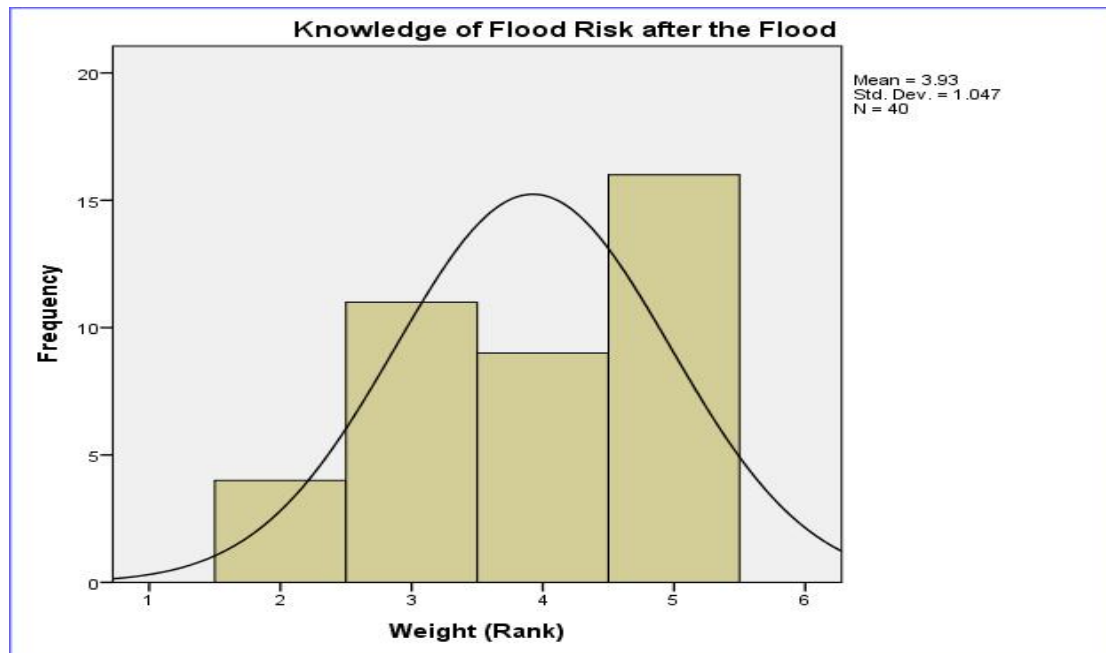


Fig. 5.9. Graph for knowledge of flood risk after flood

5.4.4. Attitude to flood disaster before and after flood happen

The term 'attitude' is used to refer to the perception or way of thinking about something.

The major assumptions regarding the interrelationship between KAP are as follows:

- Positive action (practices) regarding flood disaster is largely the function of positive attitudes.
- Positive attitudes regarding flood disaster are the functions of awareness of contemporary population knowledge issues, value of awareness, awareness of opportunities and affordability to access such opportunities.

Using the descriptive frequency analysis of SPSS software evaluate the positive and negative attitude of Sibu Sire Woreda population due to flood disaster before and after flood event happen in the Woreda. (Table 5.12), shows that the value of attitude analysis before flood happen ,17.5%,40%,32.5%,10% and 0% were represents very low(1),low(2), moderate (3),high (4) and very high (5),respectively. The people have negative attitude thinking to the flood disaster before events of flood in the Woreda and the awareness level was very low.

Table 5.11. Existing attitude to flood hazard and risk before flood event

Weight (Rank)	Frequency	Percent	Valid Percent	Attitude to flood hazard and risk
1	7	17.5	17.5	Very low
2	16	40.0	40.0	Low
3	13	32.5	32.5	Moderate
4	4	10.0	10.0	High
5	0	0	0	Very high
Total	40	100.0	100.0	

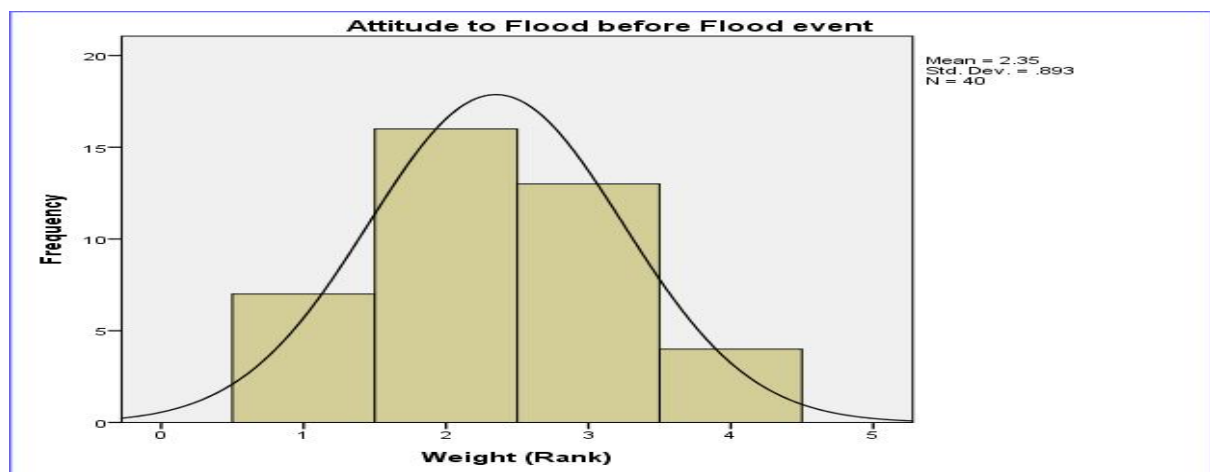


Fig. 5.10. Graph for attitude to flood before flood

(Table 5.13), and (fig.5.11), revealed that the value of attitude analysis after flood disaster happen in the Woreda, 0%, 2.5%, 32.5%, 42.5%, and 22.5% were represents very low(1),low(2), moderate (3),high (4) and very high (5),respectively. Means that the positive attitude of society due to the flood disaster after events of flood in the Woreda was increased and the awareness level was moderate.

Table 5.12. Existing attitude to flood hazard and risk after flood

Weight (Rank)	Frequency	Percent	Valid Percent	Attitude to flood hazard and risk
1	0	0	0	Very low
2	1	2.5	2.5	Low
3	13	32.5	32.5	Moderate
4	17	42.5	42.5	High
5	9	22.5	22.5	Very high
Total	40	100.0	100.0	

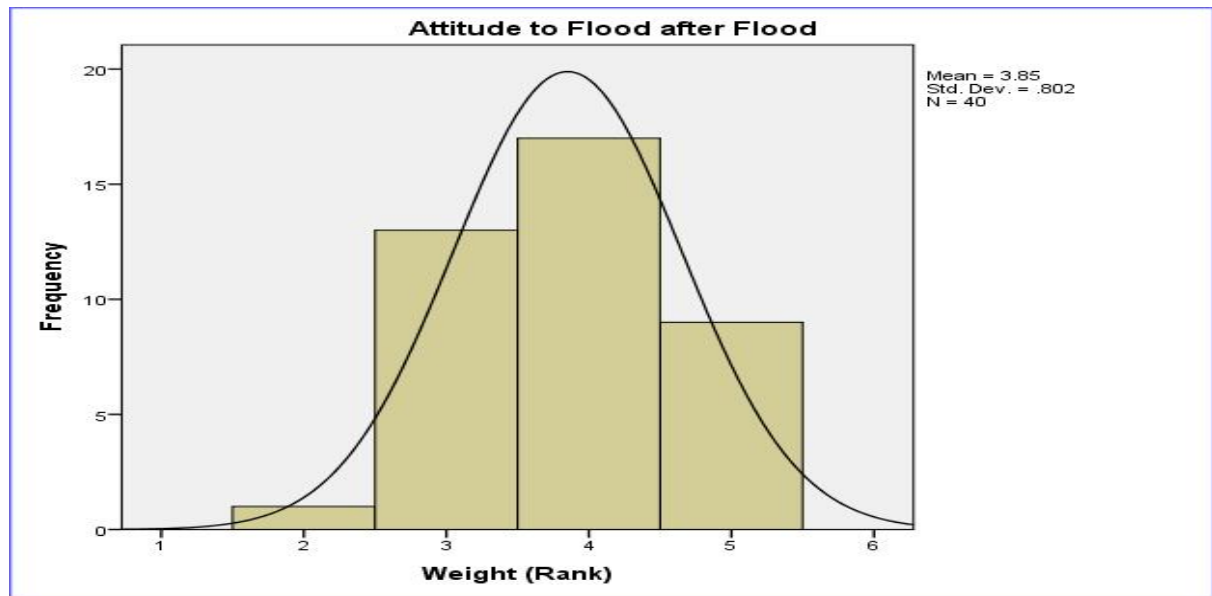


Fig. 5.11. Graph for attitude to flood after flood

5.4.5. Action (Practice) to flood disaster before and after flood events

The term 'performance' is used to refer the actions or behavior relating to knowledge of flood disaster. From the above assumptions the Positive action regarding flood disaster is largely the function of positive attitudes. For positive action, either the existing awareness can be altered or relevant programs can be introduced to minimize the effects of such determinants. The existing action of people to the flood before the event was evaluate in the table 5.14 below, as,17.5%,42.5%, 27.5%,12.5% and 0% were represents very low(1),low(2), moderate (3),high (4) and very high (5),respectively. (Fig.5.12) graph show the result of descriptive analysis of KAP respondents.

Table 5.13. Action to flood hazard and risk before flood

Weight (Rank)	Frequency	Percent	Valid Percent	Action to flood hazard and risk
1	7	17.5	17.5	Very low
2	17	42.5	42.5	Low
3	11	27.5	27.5	Moderate
4	5	12.5	12.5	High
5	0	0	0	Very high
Total	40	100.0	100.0	

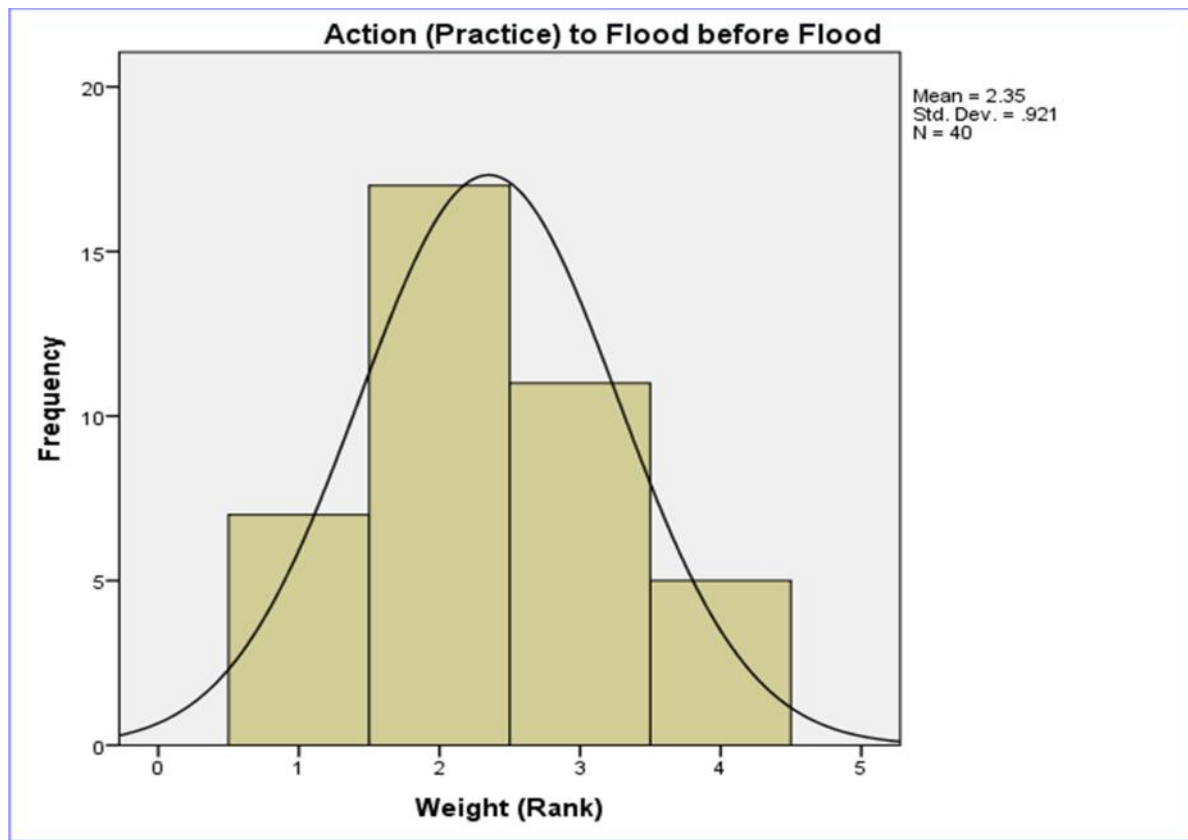


Fig. 5.12. Graph for action to flood before flood

Whereas, the existing action or performance of people to minimize disaster after the event was evaluate in the (table 5.15), and (fig.5.13), below, as,0%,12.5%, 15%,32.5% and 40% were represents very low(1),low(2), moderate (3),high (4) and very high (5),respectively.

Table 5.14. Existing action to flood hazard and risk after flood

Weight (Rank)	Frequency	Percent	Valid Percent	Action to flood hazard and risk
1	0	0	0	Very low
2	5	12.5	12.5	Low
3	6	15.0	15.0	Moderate
4	13	32.5	32.5	High
5	16	40.0	40.0	Very high
Total	40	100.0	100.0	

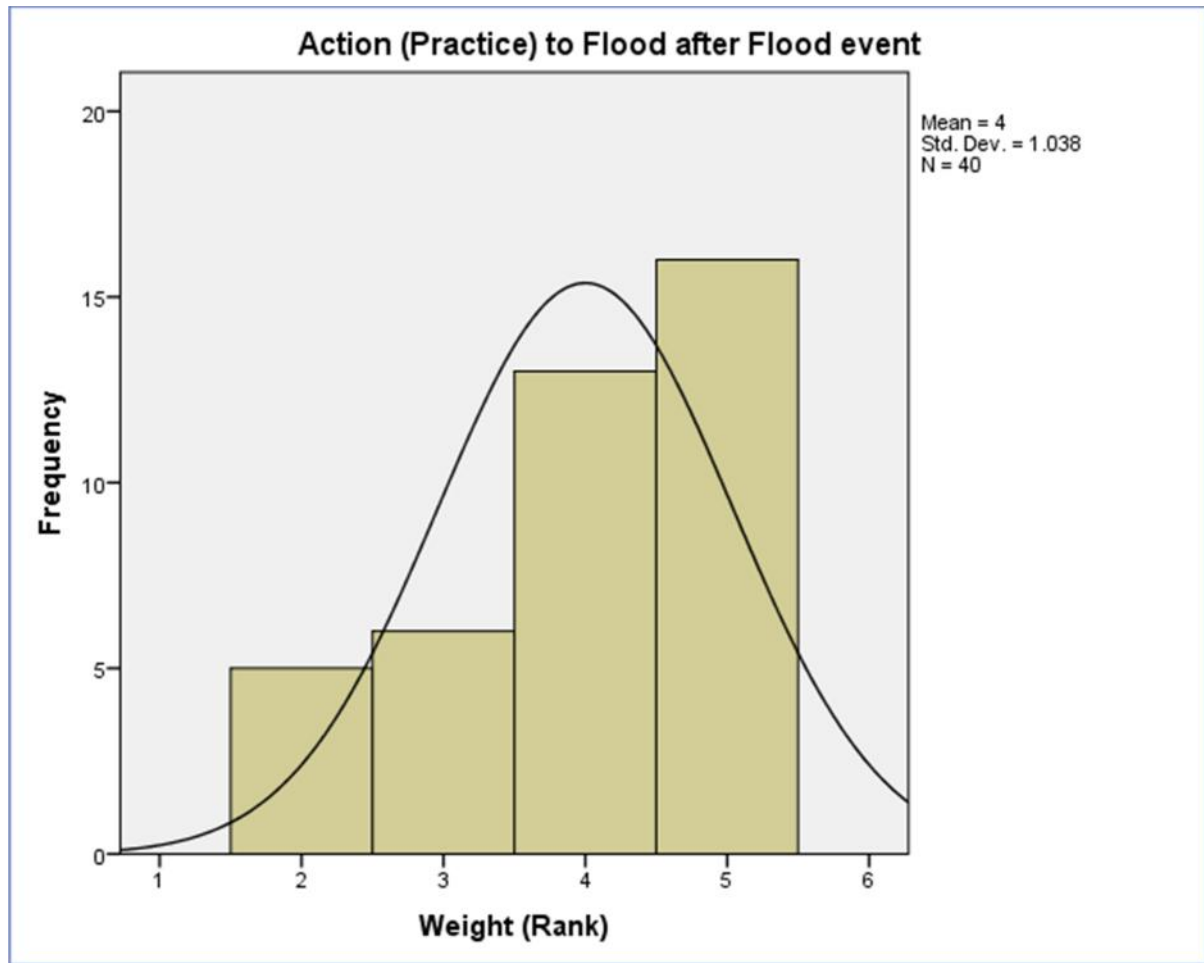


Fig. 5.13. Graph for action to flood after flood

Generally, as shown from the descriptive frequency analysis result of the SPSS software of the KAP data collected from respondents before and after the floods event, the awareness level of society was low due to the flood hazard and risk in Sibu Sire Woerda before the events and increase after the events. Hence, concluded as society of the Woreda doesn't have preparedness before the any disaster and the awareness level was very low.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

GIS technique is important to develop factors that cause flood and used to develop flood hazard and risk assessment of the study area using the multi-criteria evaluation. The basic idea of flood hazard, vulnerability and risk analysis and mapping as undertaken in this study is to control land use by flood plain zoning in order to restrict the damages. In the light of above discussion, it can be said that flood risk mapping, being an important non-structural flood management technique, will go long way in reducing flood damages in areas frequented by flood.

The study also reviewed the role of GIS in decision-making and then outlined the evaluation approach for many criteria in decision process. The design of multi criteria environment attempted to use a variety of evaluation techniques to data from GIS and present them in a manner familiar to decision makers. By integrating the evaluation techniques with GIS, it was intended that the effective factors would be evaluated more flexibly and thus more accurate decision would be made in a shorter time by the decision makers. By evaluating the criteria, the values of the criteria were classified to explain the opinions and preferences.

The study indicated that 7.26% and 2.16 % of the area of the Sibu Sire Woreda was very high flood hazard and risk zone respectively. Using Arc-GIS after analysis the flood hazard and risk depending on their causative factors the KAP study is applied to evaluate the awareness level of the Woreda society to the flood disaster by descriptive frequency analysis of SPSS technique and concluded as their preparedness to any disaster is low.

6.2. Recommendations:

This investigation provides information on flood hazard at a Catchment, Woreda level and flood risk at Woreda level that could be used for reducing vulnerability to flood disaster in Sibu Sire Woreda in particular and that of the Indris Catchment at large with the following recommendations:

- Sibu Sire Woreda blessed with ample land resources, which is one of the most agricultural development areas in Ethiopia, but its proper agricultural development has been hindered by inundation, floods and poor drainage condition. Therefore, the

responsible bodies of the Woreda as well as the region should use this flood hazard and flood risk map for better management of their agricultural development.

- The natural disaster management and environmental protection of the Woreda use this study to manage flood hazard and for land use protection strategy.
- Creating more awareness among the society concerning optimum use of natural resources, conservation systems and their benefits by concerned bodies could play significant role in minimizing of environmental risk zone. In addition, since most important factor for the land cover change in the Ethiopia, 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.
- The Woreda is important to prepare the workshop or more training for the people on environmental protection method.
- Do watershed management in the upstream area, because it use for the constant regulation.
- Raise awareness level of society towards any natural hazard.
- More studies should be undertaken using another hydrological technique, such as Hecras software based for evaluating the criteria.

6. REFERENCES

- Finan et al. (2002). T.J., C.T. West, D. Austin and T. McGuire. . Processes of adaptation to climate variability: a case study from the US Southwest. *Climate Research* . 21: 299-310.
- Keith Smith and Roy Ward. (1998). *Floods, Physical Processes and Human Impacts*.
- (2009). Retrieved from WWW2.jpl.nasa.gov.
- Agricultural and Rural development, and Disaster Management office record. (2013). *Flood Hazard and Risk impact report in Sibu Sire Woreda*.
- Amenti Abraham. (1989). Tectonic history of the Pan-African low grade belt of western Ethiopia. Ethiopian Institute of Geological Surveys. Note No. 305, 14p, Addis Ababa.
- Ashagrie. (2010). A.G, De Laat, P.J.M., De Wit, M.J.M., Tu, M., Uhlenbrook, S. Detecting the Influence of Land use Changes on Discharges and Floods in the Meuse River Basin- The Predictive Power of a Ninety-Year Rainfall-Runoff Relation. *Hydrology and Earth System Sciences*. 10, 691-701.
- Aven & Kristensen. (2005). perspectives on risk: review and discussion of the basis for establishing a unified and approach.
- Barret and Curtis. (2001). *Introduction to Environmental Remote Sensing*. 3rd ed. Chapman and Hall. London.
- Blaikie. (1994). P., R. Cannon, I. Davis and B. Wisner. *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. Routledge, New York, USA. 284 pp.
- Cochrane and Flanagan, 2000, Shamsi, 2005. (n.d.). Effects of DEM resolution in the runoff and soil loss prediction of the watershed model *Transactions of the ASAE*. 48, 109-120.
- Congalton, R.G. and K. Green. (1999). *Assessing the accuracy of remotely sensed data:: Principles and Practices*. Boca Raton FL: Lewis Publishers. 137 pp.
- CSA. (2007). *Population census data collected by Central Statistical Agency of Ethiopia* .

dahal. (2008). HAZARD AND RISK: PERCEPTION OF GLACIAL LAKE OUTBURST FLOODING FROM TSHO ROLPA LAKE, NEPAL.

Daniel Ebba. (2008). *Demographic and Socio-Economic Correlates of Agricultural Income in Sibu Sire District, East Wollega of Oromia, Ethiopia* .

De Graff, J. (1989). *Landslide activity resulting from the November 1988 storm events in Southern Thailand and associated resource recovery needs.*

DPPA. (2006). *Joint Government and Humanitarian Partners: Flash appeal for the 2006 flood disaster in Ethiopia.*

DPPA. (2006). Joint Government and Humanitarian Partners: Flash appeal for the 2006 flood disaster in Ethiopia.

DPPA. (2006). *Joint Government and Humanitarian Partners: Flash appeal for the 2006 flood disaster in Ethiopia.*

DPPA. (2006, August, 2016). *Joint Government and Humanitarian Partners: Flash appeal for the 2006 flood disaster in Ethiopia.* Retrieved from <http://www.dppc.gov.et/downloadable/reports/appeal/2006/Flood%20Appeal%20II%20MASTER%20Final.pdf> , .

DPPA. (2006). *Joint Government and Humanitarian Partners: Flash appeal for the 2006 flood disaster in Ethiopia* <http://www.dppc.gov.et/downloadable/reports/appeal/2006/Flood%20Appeal%20II%20MASTER%20Final.pdf>. Access Date: August, 2016.

Hewitt. (1997). K. *Regions of Risk: A Geographical Introduction to Disasters.* Longman,. Singapore. 389 pp.

Heywood et.al. (2002). I., Cornelius, S. and Carver, S., *An Introduction to Geographical Information System, II*nd edition, Pearson Education: Harlow.

- Hirji . (2002). Jonhson, P., Maro P., and Matiza-Chiuta,T.Defining and Mainstreaming Environmental sustainability in water Resources Management in Southern Africa. SADC, IUCN, SARDC, World Bank: Maseru/Harare/ Washington DC.
- Jayaseelan. (2001). Droughts and Floods Assessement and Monitoring Using Remote.
- Jayaseelan. (2001). Droughts and Floods Assessement and Monitoring Using Remote Sensing and GIS: Satellite Remote Sensing and GIS Applications in Agricultural Meteorology. Department of Space, Govt. of India, Hyderabad. 291-313.
- Ken Granger. (2002). *Community Risk Assessment in Mackay: A Multi-Hazard Risk Assessment*, Retrieved August 2016, from http://www.ga.gov.au/image_cache/GA4177.pdf. Access Date: .
- Kraemer and Panda. (2009). Arc Hydro for watershed delianation proceeding of the 2009 Georgia water Resources Conference,held April 27-29,2009, University of Georgia.
- Krumbein. (2002). , W.C, Graybill, F.A An Introduction to statistical models in Geology, Mc ,Hill, Mc Graw New York. 475.
- Krumbein, W.C, Graybill, F.A. (2002). An Introduction to statistical models in Geology, Mc , , . In M. G. Hill. New York.
- Leslie, A. (2006). *Hydrodynamic modelling of the 2003 Nuna River Flood Using Terrain Information Obtained from Remote Sensing Sources. International Institution for*. Retrieved from http://www.Itc.Nl/Library/Papers_2006/Msc/lirs/Leslie.Pdf.
- Lillesand. (2000 and 2004). Remote Sensing and image Interpretation: 4th ed. John Wiley & Sons, Inc. 750 pp.
- Lovett, 2008 and Shamsi, 2005. (n.d.). GIS for environmental decision- making and Application for water,wastewater and storm systems.
- Lowery. (1996). B:Hickey, W.J.; Arshad, M.A.; Lal, R. Soil Water Parameters and Soil Quality; Doran, J.W., Jones, A.J., Eds.; Methods for Assessing Soil Quality: Madison, WI, USA. pp. 143–55.

- Matiki. (2005). The floodplain management of the Shire valley (Nsanje and Chikwawa). MSc Thesis. Department of Civil Engineering. University of Zimbabwe, Unpublished.
- Matiki. (2005). The floodplain management of the Shire valley (Nsanje and Chikwawa). MSc Thesis. Department of Civil Engineering. University of Zimbabwe, Unpublished.
- Mel ancon. (1999). A GIS based watershed analysis system for Tillamook Bay, Oregon. Thesis. Master of Science in Engineering. University of Texas. USA.
- Messner. (2005). Flood damage, vulnerability and perception changes for flood damage research.
- Miller. (1997). FLOODS: People at Risk, Strategies for Prevention. *United Nations Publication*. New York and Geneva: United Nations Publication.
- Myers and White. (1993). The challenge of the Mississippi flood. *Environment*. 35, 6-35.
- Nelson. (2007). *Flood Hazards, Prediction and Human Interventions*. Tulane University. *Intute: Science, Engineering and Technology*. Retrieved from <http://www.tulane.edu/~sanelson/geol204/floodhaz.htm>.
- Nheta, D. (2003). Zambezi River Floods Drown Parts Of Caprivi. *The Zambezi*. 5 (3), Zimbabwe <http://www.sardc.net/imercsa/zambezi/zambezi/v5n3/floods.htm>.
- Nicholls. (1990). Wong, K.K. Dependence of Rainfall Variability on Mean Rainfall, Latitude, and the Southern Oscillation. *J. Clim.*, 3, 163–170.
- Nicholls. (2001). *Natural Hazards*. 23: 137-155.
- Palp & Werner. (2006). Understanding Risk perception from Natural Hazard; Examples from Germany. *Risk 21-Coping with due to Natural Hazard in the 21 st century*. .
- Raaijmakers et. al. (2008). Flood risk perception and spatial multi-criteria analysis: An exploratory research for hazard mitigation.
- Saaty, .. (1999). *GIS and Multicriteria Decision Analysis*, . New York, NY: John Wiley and Sons.

- Shook, G. (1997). An assessment of disaster risk and its management in Thailand Disasters 21 (1): . 77-88.
- Star, J. and Estes, J. (2005). *Geographic Information system: An Introduction, Engle woods*.
- Strahler. (1964). Quantitative Geomorphology of Drainage basins and Channel network. In Handbook of Applied Hydrology; Mc Graw Hill: New York, NY, USA., pp. 39–76.
- Strahler. (1999). Quantitative Geomorphology of Drainage basins and Channel network.
- Teller. (1967). Report Paper: Impact of Forest Land-Use on Floods. FAO Forestry Industries Division, European Forestry Commission.
- UN. (2004). Towards Sustainable Development in Africa.
- UNDP. (2000). *United Nations, 1997. Floods. People at Risk, Strategies for Prevention. Department Of Humanitarian Affairs. Mozambique and UNDP, 2000. Flood in Mozambique Final report; International Conference, Rome*. New York and Geneva.
- UNISDR. (2009). *Terminology on Disaster Risk Reduction*. Retrieved from http://www.unisdr.org/files/3004_fireandmud.pdf.
- United Nations. (1997). *Floods. People at Risk, Strategies for Prevention. Department Of Humanitarian Affairs. New York and Geneva. Mozambique and UNDP, 2000. Flood in Mozambique Final report; International Conference, Rome*. New York and Geneva.
- UNOCHA. (2010). *Weekly humanitarian highlights in Ethiopia*.
- Vilanculos, A. (2006). MSc Thesis: Towards Improving Flood Forecasting and Early Warning Systems through Integrated Technology in the Limpopo Basin. Department of Civil Engineering. University of Zimbabwe. Unpublished.
- Wachinger & Renn. (2010). Perspectives on social capacity building for natural hazards.
- Woreda Agricultural and Rural Development . (2013). *Report of natural hazard disaster*.

World Bank. (2001). *'Flood Control in Bangladesh; A Plan for Action'*, World Bank Technical, Asia Region Technical Department, 119.

World Meteorological Organization. (2010). *Associated Programme Flood Management Technical Document No. 1, 2nd Edition*. Retrieved from <http://www.wmo.ch/pages/prog/dpm/disasternaturalhazards.html#floods>.

7. APPENDICES

1. Questionnaire sample survey
2. The Pair Comparison Matrix of the factors affecting Flood hazard.
3. Mean Annual Rainfall (mm) of 20 Years (Source: NMA, 2016)
4. Total population at kebele level of Sibu Sire Woreda (Source: CSA, 2007).
5. Monthly mean temperature (°C) (Source: CSA, 2007).
1. Questionnaire sample survey

Code: _____

Adama Science and Technology University

Department of Geomatics Engineering

I. Random Systematic Sample Questionnaire survey of Flood Hazard and Risk Impact in Sibu Sire Woreda

The purpose of this questionnaire is to collect survey data for the research study on the “GIS based flood Hazard and Risk Assessment: A case of Sibu Sire Woreda in partial fulfillment of (MSC) degree in Geodesy and Geomatics Engineering. Thus, your frank, sincere and timely response to the items in the questionnaire helps to meet the objective of the study. Thus I ask you to fill the information on the space provided or positively respond to the data collectors. The information you provide is used only for the purpose of this study and will be highly confidential.

I would like to thank you in advance for your cooperation!

General Information

1. Region _____ Zone _____ Woreda _____ Kebele _____
2. Weather Condition above sea levels
 - i. Dega _____
 - ii. Weyina-Dega _____
 - iii. Kola _____
3. Sex: 1. Male__ 2. Female__ 3. Age: a. (0-25) __ b. (25-45) __ c. (45-60) __ d. Above
4. Ethnicity: i. Amhara__ ii. Oromo__ iii. Tigre__ iv. Gurage__ v. others specify if any__
6. Educational level: a. Illiterate __ b. First cycle (1-4) __ c. First cycle (5-8) __ d. Secondary __ e. Education (9-12) __ f. Certificate and above _____
8. Religion: i. Orthodox__ ii. Muslim__ iii. Protestant__ iv. Catholic __ v. Specify if any----

1. Sample Random Systematic questionnaire Survey

The sample random systematic questionnaire survey contains knowledge, action and attitude of the people due to the flooding. These are ranked as 1, 2, 3, 4 and 5 for very low, low, moderate, high and very high, respectively to the knowledge, action and attitude about the flood due to the people of the study area.

Part I: - Knowledge Assessment

- _____ 1. How do you rate your knowledge regarding the cause of flood in the following times (i.e. before 2005 and after 2005's)?
- a. 1 , b. 2 , c. 3 , d. 4 , e.5
- _____ 2. How do you rate your knowledge regarding flood vulnerability in the times (i.e. before 2005 and after 2005's)?
- b. 1 b. 2 c. 3 d. 4 e. 5
- _____ 3. How do you rate your knowledge regarding flood risk in the following (i.e. before 2005 and after 2005's)?
- a. 1 b. 2 c. 3 d. 4 e. 5

Part II: Action Assessment

- _____ 4. How do you rate your action related to pre-flooding event?
- a. 1 b. 2 c. 3 d. 4 e.5
- _____ 5. How do you rate your action related to post flooding event?
- a. 1 b. 2 c. 3 d. 4 e.5

Part III. Attitude Assessment

- _____ 6. How do you rate your attitude towards pre-flooding event?
- a. 1 b. 2 c. 3 d. 4 e.5
- _____ 7. How do you rate your attitude towards post flooding event?
- a. 1 b. 2 c. 3 d. 4 e.5

Appendix 2. The Pair Comparison Matrix of the factors affecting Flood hazard

WEIGHT - AHP weight derivation

Pairwise Comparison 9 Point Continuous Rating Scale

1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely
Less Important					More Important			

Pairwise comparison file to be saved :

	D:\Flood Hazard 1	D:\Flood Hazard 5	D:\Flood Hazard 4	D:\Flood Hazard 3	D:\Flood Hazard 2	D:\Flood Hazard 1/2
D:\Flood Hazard 1	1					
D:\Flood Hazard 5		1				
D:\Flood Hazard 4		1/3	1			
D:\Flood Hazard 3		1/5	1/2	1		
D:\Flood Hazard 2		1/4	1/3	2	1	
D:\Flood Hazard 1/2		1/5	1/4	1/3	1/4	1

Compare the relative importance of D:\Flood Hazard\Indris_Catchment First Draft\Exp

Appendix 3. Mean Annual Rainfall (mm) of 20 Years (Source: NMA, 2016)

Station Name	Long.	Lat.	Elev.	Mean Monthly Rainfall												Mean Annual
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Nekemte	36.46	9.08	2080	11.5	11.5	46.9	88.4	259.5	394	391	378	291	153	49	16	2100
Shambu	37.12	9.57	2460	10	14.2	39	61.3	174.7	250.5	328	238.2	206.5	74.3	29.5	13	1439
Arjo	36.5	8.75	2565	13.7	14	59.5	106.8	199.3	287.8	338	301.3	293.5	103.2	48.3	23.7	1789.3
Bedele	36.3	8.45	2011	16.6	18.7	68.2	98.3	213.3	286.7	274.7	289.7	310.7	152.2	33.8	18.9	1781.2
Ejaji	37.32	8.99	1732	17.5	10.8	52.9	64	135.2	221.8	254.4	273.3	177.6	78.1	32.6	12	1330
G/Ayana	36.62	9.87	1850	4.8	8	34.2	64.9	183.2	257.3	295.8	275.3	255.4	116	32	8.6	1535.9

Appendix 4. Total population at kebele level of Sibu Sire Woreda (source: CSA, 2007)

Geographical Area by name	Total Population			Conventional Households		
	Both Sexes	Male	Female	Persons	Households	Housing Units
SIRE-TOWN	10,243	5,043	5,200	10,009	2,371	2,288
DENGEJO GUYO	5,006	2,527	2,479	4,996	1,102	1,083
BEKO JIMMA	8,270	4,362	3,908	8,265	1,843	1,793
HAGELO TULEMA	3,862	1,942	1,920	3,862	748	739
HONBOSE HOB0	3,794	1,869	1,925	3,794	741	721
DICHO						
ABAGERMAMA	4,402	2,187	2,215	4,402	834	812
BARO TITITA	2,881	1,449	1,432	2,859	578	569
BUJURA AMUMA	4,461	2,189	2,272	4,461	899	876
BEKENISA BECHERO	2,697	1,286	1,411	2,697	537	516
BURKA TAL0	6,345	3,063	3,282	6,338	1,236	1,214
DAME CHEKA	3,249	1,567	1,682	3,249	645	623
FELAMO YUBDO	4,655	2,235	2,420	4,652	920	898
CHERI JARSO	5,350	2,667	2,683	5,344	1,091	1,061
BABO KUWE	5,140	2,525	2,615	5,132	974	948
CHEFE JALALE	5,422	2,719	2,703	5,413	1,089	1,043
Oda Buke	5,681	2,828	2,853	5,648	1,166	1,139
WELI GELTE	4,743	2,403	2,340	4,738	1,005	990
JARSO WAMA	4,793	2,422	2,371	4,787	959	935
BIKILA	4,564	2,206	2,358	4,564	905	894
LELISA	6,670	3,228	3,442	6,667	1,335	1,307

Appendix 5. Monthly mean temperature (°C) (Source: CSA, 2005)

	Monthly mean temperature (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min.	15.2	14.5	19.2	19.8	19.7	21	18.6	17.5	17.4	16.5	16.1	14.3
Max.	31.2	32.5	33	34	35.2	36	30	31.5	28.7	31	29	28.9