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**School of Civil and Environmental Engineering  
program MSc in Geodesy and Geomatics, specialization in  
Geomatics**

**Evaluation of the impact of land use/land cover changes on the floods of  
Addis Ababa city**

by:

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Advisor

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**A Research Submitted to the School of Graduate Studies in Partial Fulfilment of the  
Requirements for the Degree of Master of Science in Geomatics Engineering**

July ,2023

Addis Ababa,Ethiopia



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ADDIS ABABA UNIVERSITY  
ADDIS ABABA INSTITUTE OF TECHNOLOGY  
SCHOOL OF GRADUATE STUDIES

School of Civil and Environmental Engineering  
program MSc in Geodesy and Geomatics, specialization in Geomatics

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Evaluation of the impact of land use/land cover changes on the floods of Addis Ababa city

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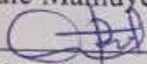
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## DECLARATION

I certify that the research work entitled, Evaluation of the impact of land use/ land cover changes on the floods of Addis Ababa city. The work has not been presented for any degree at any other University. The material obtained from other sources has been properly acknowledged in the thesis.

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## ABSTRACT

Land use and land cover (LULC) changes are continuous, and both natural and man-made environments drive it over time. These changes are affecting the hydrological system. Flooding is one of the environmental problems in Addis Ababa city. This research aims at evaluating the spatiotemporal changes of LULC changes and their impact on flooding in Addis Ababa city., Hence to investigate this, the present study adopt a supervised classification technique and change detection techniques. This study uses Remote sensing (RS), geographical information system (GIS) and Earth Resource Data Analysis System (ERDAS) software. Accordingly, Satellite images were utilized to monitor LULC changes from year 1992-2021 for the five identified LULC classes. The finding of the study showed that, the built-up area increased from 13,013.04ha in 1992 to 34398.05ha in 2021, barren land decreased from 14,973.75ha to 6950.25 ha, agricultural Land decreased from 13114.15 ha to 3993.97 ha, Forest decrease from 4688.16 ha to 1924.90 and a slight change occurred in water body decrease from 6161.07ha to 4683.00 ha. Build up area exhibited the most noticeable changes (25.05 % to 66.21%,) from 1992 to 2021, which came from agricultural land and barren land. The flood hazard analysis was computed using the multi-criteria evaluation (MCE) technique by selecting six flood contributing factors (slope, soil type, elevation, land use/land cover, drainage density, and Rainfall). Then a flood hazard map was developed using the Analytical Hierarchy Process (AHP) and further fine-tuned with sensitivity analysis for rating the weighted percentage each factor in contributing flood aggravation. The study revealed that rain fall (26%), drainage density (23%) and LULC (20%) significantly impact for flood hazard generating. While, elevation (12) and slope (12%) have a medium impact whereas soil type showed low impacts in flood contributing process. The developed flood hazard map from this research work showed that a high flood hazard has imposed by the flood in the Nifas silk lasfto and Aakaki kality sub city of the study area. This study's results provides valuable information for the city administration on the identified flood risk-prone locations for implementing emergency plan and future long term flood mitigation measures. It also provides useful knowledge for policy-relevant land administration for future development related to land use plan associated with flood.

**Keywords:** Addis Ababa, LULC , Flood, Remote sensing, GIS.

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**List of ACRONYMS**

GIS	Geographical information system
RS	Remote sensing
LULC	Land use and land cover
MCA	Multi-Criteria Analysis
AHP	Analytical Hierarchy Process
MCE	Multi-Criteria Evaluation

## CHAPTER ONE

### 1. INTRODUCTION

#### 1.1 Background

Land is the , primary natural resource on which economic, social infrastructure and other human activity are taken (Mikias, 2015). Land use and land cover (LULC) are closely related and distinct terms. LULC patterns are the results of natural and human use of social and economic elements over time and space. The information is essential for monitoring activity and information on the ground surface. LULC is the most prominent form of the global environmental change phenomenon occurring at spatial and temporal scales (Wubie et al., 2016). The relationship between LULC change and its causative factors is complex and dynamic (Wubie et al., 2016).

LULC change has become a central and important component in current strategies for managing natural resources and monitoring environmental changes (Rawat et al., 2013). The LULC change is influenced by various natural and humans trying to meet diverse needs such as residential, industrial, agricultural, mining, and other infrastructural facilities and are major concerns associated with area's economic and sustainable development (Rawat et al., 2013). LULC change affects many parts of the earth system such as, climate, hydrology, global biodiversity and the fundamental sustainability of lands.

The major causes of urban floods include increased precipitation due to climate change effect, change in LULC and related hydrological impacts (Zope et al., 2017). LULC change dynamics are essential for monitoring, evaluating, protecting and planning for earth resources (Rawat et al., 2013). The impact of LULC change on the hydrological process is the main reason for urban flooding. The flood can affect humans and environment. Flooding in urban areas is a major natural hazard causing loss of life, property damage and infrastructure.

LULC change and flood hazard maps are useful tools for flood risk mitigation and protection measures to identify flood vulnerable areas. Addis Ababa City is currently one of the urban areas exposed to flooding due to LULC change, poor or no implementation of urban flood management strategies, and global joint climate change impact (Jemberie & Melesse, 2021). In addition, the low-level drainage standards, poor drainage capacity, improper drainage alignment, aged drainage facilities and complicated drainage pipe networks with unreasonable settings, rapid housing development along river banks, and interruption of drainage facilities with other urban utility lines. To mitigate and protect from potential flood risk in urban areas, we need to improve our understanding of the possible impacts of the ubiquitous uncertainty of urban flood projection (Jung et al., 2011). A thorough risk management strategy is needed to reduce flood disasters' effects.

Different methods are used to evaluate the relationship between LULC change and flood. Traditional inventories can monitor LULC changes. Geographic information systems (GIS) and remote sensing, represent useful tools for assessing the LULC changes and flood. Satellite remote

sensing provides greater information on the geographic distribution of land use and changes, along with cost and time savings advantages for regional size areas (Yuan et al., 2005).

The role of GIS is to promote to process remotely sensed data or other source data. Researchers can now access satellite photos from any region of the world with short revisit cycles and a variety of spatial resolutions because to ongoing developments in remote sensing. Particularly Remarkably, the spatial resolution of Landsat sensors is sufficient and sufficiently detailed to characterize the processes that affect LULC change in the study area (Costache et al., 2020).

RS and GIS have mainly been handy in flood management. Through modeling coupled with RS and GIS use, floods can be predicted and the flood vulnerable and flood risk areas can be mapped out (Opolot, 2013). This information is crucial for policymakers and the general population, particularly in the affected areas, to provide early warnings, conduct evacuation drills, and promote general preparedness. Post flood analyses can also be done using RS and GIS techniques. In this way, an idea can be computed regarding economic losses, infrastructural damages, and reconstruction costs (Opolot, 2013).

Timely and precise information about LULC change detection of earth surface is crucial for understanding the relationship and interaction between human and natural phenomenon for better management of decision-making. This research aims to assess the LULC change and also the effect of LULC change on flooding in Addis Ababa.

## **1.2 Statement of the Problem**

Floods resulting from LULC change and excessive Rainfall within a short duration of time. The flash floods, generated by the surface runoff on the slopes, represent one of the most dangerous natural hazards producing the most significant damage to human communities. Consequently, it is essential to study and monitor the areas holding high potential for surface runoff (Costache et al., 2020). In Ethiopia, urban floods incidents are becoming a severe problem in recent years. They are mainly associated with poorly designed urban drainage systems and land use planning (Nigusse & Adhanom, 2019).

Addis Ababa City is currently one of the urban areas exposed to flooding due to LULC change, inefficient land use, and poor or no implementation of urban flood management strategies. According to a report done by the Addis Ababa City Fire, Emergency Prevention and Rescue Agency (AAFEPR) in 2017 shows that more than 70 flood incidences were recorded following the 2017 rainy season and caused more than US\$740,000 worth of damages to infrastructure and private property (Mohamed & Worku, 2021).

The status of LULC change and flood hazard in Addis Ababa city has not been properly studied and well documented. Studying the LULC changes associated on flood risk impacts are very important for flood risk reduction. This allows decision-makers to go appropriate policies to

manage. This allows decision-makers to drive proper policies to manage the lands sustainably. thus, the study will evaluate the LULC change and impact on flooding in Addis Ababa.



*Figure 1. Flash Floods in Addis Ababa, Ethiopia, 17 August 2021. Photo via Mayor of Addis Ababa / Twitter*

### **1.3. Objective**

This research study has the following objectives

#### **1.3.1 Main objective**

This study's main objective analyzing the impact of LULC change on urban flooding in Addis Ababa.

#### **1.3.2 Specific objective**

The specific objective of the research is described as follows: -

- To analyze the spatio-temporal change in LULC of Addis Ababa city during the period of 1992,2002,2014 and 2021.
- To analyze the impact of LULC change on flood occurrence

- To identify flood risk areas in Addis Ababa city

#### **1.4 Scope of the study**

This study only concentrated to analyzing the impact of LULC change on urban flooding in Addis Ababa.

#### **1.5 Limitation of the study**

Limitations are matters and occurrence that arise in a study which are out of the researcher's control(Simon & Goes, 2013). The limitation of this study is actual flood hazard data for the year 1992,2002 and 2014 and enough and well documented study based on flood in addis ababa city.

#### **1.6 Research Questions**

To address the stated objectives, this research focus on answering the following research questions:

- To what extent and rate of LULC changes have occurred in Addis Ababa City
- What is the significance of land use change on urban flooding?
- Which area of the sub-city are flood-prone area?
- What type of intervention will be implemented to alleviate or mitigate flood hazards?

#### **1.7 Significance of the study**

This research analyzes the LULC change in Addis Ababa city and examine the LULC change impacts on flooding. This information will be essential for understanding LULC change and its effects on the frequency of floods between 1992 and 2022. For the Addis Ababa City Administration and 'AAFEPPRA's for management choices involving land use management, planning, and flood mitigation measures.

#### **1.8 Organization of the Thesis**

The remaining part of the thesis is organized into four chapters. The second chapter contains a review of related literature in areas of lulc, change detection technique of lulc , flood and methods of investigation. The third chapter methodology and procedure to develop flood hazard map. Then, results, analysis, and discussion are presented in chapter four. Finally, chapter five provides the conclusions made and the recommendations forwarded.

## CHAPTER TWO

### 2. LITERATURE REVIEW

#### 2.1 Remote sensing

Remote sensing is an art of obtaining data or information about the object from a distance without the physical contact with the object. Technically, it measures electromagnetic energy that is emitted or may be reflected by the object. Remote sensing is very useful in collecting data from areas that are inaccessible for human beings to reach. Generally, remote sensing technique is used for collecting data of Earth and the atmosphere especially with the help of satellite(Gautam & Mehta, 2015)

remote sensing methods are based on the use of image data acquired by a sensor such as aerial cameras, scanners or a radar. Taking a remote sensing approach means that information is derived from the image data, which form a (limited) representation of the real world. Notice, however, that increasingly (remote) sensing devices are used in the field that can acquire data in a fashion similar to air- or space borne sensors (Pohl & Reeves, 2004).

It is well known that the soil attribute's spectral answer differs for various areas of electromagnetic spectrum. It is well known that spectral answer of the soil attribute is different for various areas of electromagnetic spectrum. Remote sensing skill offers this through nondestructive synoptic screening capacities. These sensed measures assist distantly in detecting and recognizing the globe surface trait (Ennouri et al., 2019).

#### 2.2 Geographical information system (GIS)

Geography can be defined as a scientific discipline which aims at studying the physical, biological and human phenomena located on the 'Earth's surface. The possibility of locating objects is particularly useful for users responsible for land management. A GIS provides pertinent data for a portion of the 'Earth's surface. It prepares, processes and analyses data, converting them into digital information with carto- graphic production, spatial analysis and decision aids as the end purpose (Cances et al., 2000)

GIS is a special case of information systems where the database consists of observations on spatially distributed features, activities, or events, which are definable in space as points, lines, or

areas. GIS manipulates data about the points, lines, and areas to retrieve data for ad hoc queries and analyses. A true GIS is designed to accept, organize, statistically analyze, and display diverse spatial information geographically referenced to a standard coordinate system of a particular projection and scale. GIS can handle large volumes of spatial data derived from a variety of sources such as field surveys, aerial surveys, and space remote sensing, in addition to the already existing maps and reports. Remote-sensing satellite imagery and GPS are promising sources for data input in GIS. Before the generation of any spatial data, one has to understand the available data types, data analysis procedures, and their capabilities in GIS to get realistic outputs (Reddy, 2018)

GIS technologies integrate a range of geographical information into a single analytical model, in which diverse data are "georeferenced" to cartographic projections (Maliene et al., 2011)

### **2.3 multi-Criteria Analysis**

Multi-Criteria Analysis (MCA) is used to analyze a series of alternatives or objectives with a view to ranking them from the most preferable to the least preferable using a structured approach. The final results of MCA are often a set of weights linked to the various objectives (Papaioannou et al., 2015). MCA necessitates the involvement of specialists with specific expertise and experience, as well as varying judgements and assessments. In such methods, the weighting process is done subjectively, which depends on the expert's opinion (Mahmoody Vanolya & Jelokhani-Niaraki, 2021). One of the multi-criteria analysis (MCA) approaches is the Analytical Hierarchy Process (AHP), structures the factors into a hierarchical framework (Papaioannou et al., 2015)

### **2.4 Analytical Hierarchy Process**

In the 1970s, Thomas L. Saaty developed the analytic hierarchy process (AHP) technique, which constructs a decision-making problem in various hierarchies as goal, criteria, sub-criteria, and decision alternatives (Sipahi & Timor, 2010).

The AHP method is a semi quantitative approach that allows criteria weight estimation relying on the experts' view of the relative importance of criteria against another for flooding. The competence of the AHP method depends on the quality of the subjective judgment of the experts (Dash & Sar, 2020). It comprises six major steps: problem definition; decomposing the problem into a hierarchy; carrying out pair-wise comparison; calculating the maximum eigenvalues and eigenvectors; calculating the consistency ratio to check the consistency of the

matrix; and aggregating the relative important weights of a decision to arrive at the final weighting for decision alternatives (Aragonés-Beltrán et al., 2017)

The AHP uses pairwise comparison to allocate weights to the elements of each level, measuring their relative importance by using Saaty's 1-to-9 scale.

## **2.5 Land use and land cover changes**

Land-use and land-cover change are used to describe the human modification of the planet's surface. The relationship between land use/land cover change and its driving factors is complicated and dynamic (Bufebo & Elias, 2021).

Land cover refers to the physical and biological cover over the surface of Land, including water, vegetation, bare soil, and artificial structures. Land use is a more complicated term. Natural scientists define land use in terms of syndromes of human activities such as agriculture, forestry, and building construction that alter land surface processes, including biogeochemistry, hydrology, and biodiversity. Social scientists and land managers define land use more broadly to include the social and economic purposes and contexts for and within which lands are managed (or left unmanaged), such as subsistence versus commercial agriculture, rented vs. owned, or private vs. public land (Ellis, 2006).

The cause of LULC change can be direct or indirect. The natural causes involve a physical action on land cover and are usually limited to a recurrent set of activities such as agricultural expansion, wood extraction and infrastructure construction. The indirect causes are formed by a complex of social, political, economic, demographic, technological, cultural and biophysical variables that constitute structural conditions in human-environment relations (Geist et al., 2006).

The information of LULC change is essential to reconstruct past land use and land cover changes, as well as to predict future changes, and thus may help to elaborate sustainable management practices aimed at preserving essential landscape functions (Kavian & Jafarian Jeloudar, 2011)

## **2.6 Flood Hazard Map**

Floods are unpredictable and occur naturally and can happen almost anywhere. They may not even be near a body of water, although river and coastal flooding are two of the most common

types. Heavy rain, poor drainage, and even nearby construction projects can put you at risk for flood damage. Because flood risk is always changing, communities use tools to understand their risk and take action to protect their families, homes and businesses.

Flood hazard maps are one tool communities use to know which areas have the highest risk of flooding. The flood hazard maps aim is to minimize the damage in case of flood by giving information to the residents in advance (Shidawara, 1999).

Model Builder to generate flood hazard map. The flood hazard analysis was will be computed using the multi-criteria evaluation (MCE) technique. To run MCE, we will select flood causative factors such as slope, soil type, elevation, land use/land cover, drainage density, and rainfall will develop and weight. Then weight overlay technique will conduct in ArcGIS. Considering the degree of loss to be total for the study area, the vulnerability is assumed to be one. Finally, layers of elements at risk (population density and land use) and flood hazards were overlaid using weight overlay analysis techniques in GIS environment to generate a flood risk map of the Addis Ababa.

Satellite remote sensing image processing algorithms and geographical information system (GIS) approaches will be implemented to accomplish the main objective of the study be implemented to accomplish the study, i.e., to analyze the land-use change and its impact on the flood. According to the workflow summaries in Figure 7, a land-use change analysis will be conducted to determine how much alterations have taken place in the Addis Ababa during the period 1992- 2021. Further, a comparison between flood and Rainfall of 1992-2021 will be conduct to correlate the flood conditions. The impact of land-use changes on 1992- 2021. flood will be analyzed based on the findings of these investigations illustrated in Figure 7.

### **2.7 change detection of land use and land cover**

change detection is the process of determining changes in an object's or phenomenon's state by monitoring it at various intervals. Change detection is an important process in monitoring and managing natural resources and urban development because it provides a quantitative analysis of the spatial distribution of the population of interest (Opeyemi, 2006).

Timely and accurate change detection of ' Earth's surface features provides the foundation for better understanding of relationships and interactions between human and natural phenomena to

better manage and use resources. In general, change detection involves the application of multi-temporal datasets to quantitatively analyze the temporal effects of the phenomenon(Lu et al., 2004).

To properly inventory and track LULC changes, remote sensing offers a reliable data source from which updated land-cover information can be retrieved. Therefore, remotely sensed data is a potential source of LULC information that may be properly assessed and monitored at a low cost (Francis, 2012).

Information on LULC and possibilities for their optimal use is essential for selecting, planning and implementation of selecting and implementing land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting from changing demands of the increasing population (Tiwari & Saxena, 2011). The accuracy assessment of the classifying images of 1992- 2021 will evaluate by using the ground data.

## **2.8 Geographical information system and remote sensing for Land use and land cover change**

The Remote Sensing and Geographic Information System have proved to be very important in assessing and analyzing land use and land cover changes (Chaudhry et al., 2015) The study of land use and land cover change has been revolutionized by satellite-based remote sensing, which can offer synoptic information on land use and land cover at a specific time and location. The quantitative analysis and identification of surface changes' characteristics and processes can be analyzed from the different periods of remote sensing data.

In the last three decades, remote sensing technologies and methods have evolved dramatically to include a suite of sensors operating at a wide range of imaging scales with potential interest and importance to planners and land managers. Coupled with the ready availability of historical remote sensing data, the reduction in data cost and increased resolution from satellite platforms, remote sensing technology appears poised to make an even more significant impact on planning agencies and land management initiatives involved in monitoring land-cover and land-use change at a variety of spatial scales (Rogan & Chen, 2004)

In recent years, the significance of spatial data technologies, especially remotely sensed data and geographic information systems (GIS), has greatly increased (Tadesse et al., 2001).

Remote sensing data obtained from satellites and aerial platforms are valuable sources of information providing up-to-date information about our natural resources, and city infrastructure facilities. GIS analyses will give the actual area of each land use class and the area of change, through the overlay operation(Tadesse et al., 2001).

### **2.9 Geographical information system and remote sensing technique for flooding**

Remote Sensing (RS) and Geographical Information Systems (GIS) have mainly been handy in flood management. Through modelling coupled with RS and GIS use, floods can be predicted and the flood vulnerable and flood risk areas can be mapped out. This information is important to the policymakers and the public, especially in the affected areas, in terms of providing early warnings, evacuation exercises and general preparedness. Post flood analyses can also be done using RS and GIS techniques. In this way, an idea can be computed regarding economic losses, infrastructural damages, and reconstruction costs (Opolot, 2013).

### **2.10 The impact of land use and land cover changes on hydrological regime**

Changes in land use patterns certainly provide many social and economic benefits. However, land use changes also directly impact the natural environment, affecting directly impact the natural environment, negatively affecting natural resources availability such as soil and water. Changes in LULC have an on natural systems' capacity to provide human needs. They also impact how vulnerable places and people are to socio-political, economic, and climatic changes.(Sulaiman et al.,2011)

LULC changes have a significant impact on water quantity through relevant hydrological processes, LULC planning and management directly affect the sustainability of water resources(Awotwi et al., 2015).

Land surface characteristics can significantly influence a watershed's hydrology by affecting rainfall infiltration, runoff generation, overland and channel flows, and other hydrological processes. Thus, one of the ways that human activities have changed the regional hydrological cycle in many areas is by changing the LULC (Li et al., 2019).

LULC change influences basin hydrological responses by dividing rainfall paths into sub-surface, surface runoff, and flow back to the atmosphere in evaporation and transpiration. Land-cover changes are vastly prominent in the developing countries that are characterized by agriculture-based economies and rapidly increasing human population. The changes in water availability due to LULC and climate changes, compounded with rapidly growing population and increase in per capita water demand, will adversely affect the food, water and energy security of those countries (Tekalegn and Diekkrüger, 2017)

LULC change is one of the important human interventions altering surface and ground water quality and quantity. The study of a catchment's hydrological cycle and hydrological response have become very complex due to complicated interrelationship between various hydrological components such as precipitation, evaporation, transpiration, infiltration, and runoff (Dwarakish & Ganasri, 2015).

The Land surrounding the City of Addis Ababa has undergone tremendous transformation due to increased agriculture, industry, and urban expansion activity. These land-use changes affect the ecosystem in terms of land cover, land quality and capability, weather and climate, quantity of land that can be sustained, and population and socio-economic determinants (Tadesse et al., 2001). There for LULC change have significant effect on hydrological process.

### **2.11 The impact of flood in Ethiopia**

Flood is a natural action, but mankind's activities accelerate flooding. It occurs at irregular intervals and varies in size area of extent and duration (Legese & Gumi, 2020).

Flood risk is one of the most important environmental and societal issue risk is One of the most important environmental and societal issues. Flood can occur in many parts of the world as riverine, flash or urban, and coastal floods, and causes impacts to people, properties, infrastructures, and the environment. Flood can occur in many parts of the world as riverine, flash or urban, and coastal floods, and causes impacts to people, properties, infrastructures, and the environment. Flood risk increases as people seek the benefits of living near water and encroach on flood vulnerable areas. Flood risk increases as people seek the benefits of living near water and encroach on flood vulnerable areas. Flooding is frequently brought on by factors including rainfall

quantity and duration, river flow, topography, soil conditions, previous conditions, ground cover, and other natural and man-made causes like climate change (Mamo et al., 2019).

Ethiopia has a particularly variable climate, Land of droughts and floodings. Floods are often explained as excess flows exceeding the transporting capacity of the river channel, lakes, ponds, reservoirs, system, dam, and the other water bodies, whereby water inundates outside the water bodies areas (Legese & Gumi, 2020).

In many river systems of Ethiopia, floods can cause a range of impacts and risks such as pollution of drinking water, death and injury, the distraction of houses and lively hood, displacement, and distraction of the community and wildlife. These days, many parts of Ethiopia are affected by flash, urban, and riverine floods frequently during the rainy season triggered by heavy rainfall episodes (Mamo et al., 2019)

## CHAPTER THREE

### 3. METHODOLOGY

#### 3.1-Study area

Addis Ababa lies on the western edge of the Rift Valley escarpment at 9°2' Latitude and 36°45' longitude (Wubneh, 2013). Addis Ababa has been the capital of the country over a century and as a result it is one of the fastest growing metropolitan areas in Ethiopia with a current population of about 3.1 million in an area of 530 km<sup>2</sup> and located in the highlands with an elevation of around 2300 m. To the north, nearer the Entoto Mountain ranges, the height can increase by more than 3000 meters. Data for the years 1951 to 2004 show that the annual rainfall can range from 918 to 1568 mm. The temperature of this area can range from 10°–23°C (Moges et al., 2014) .

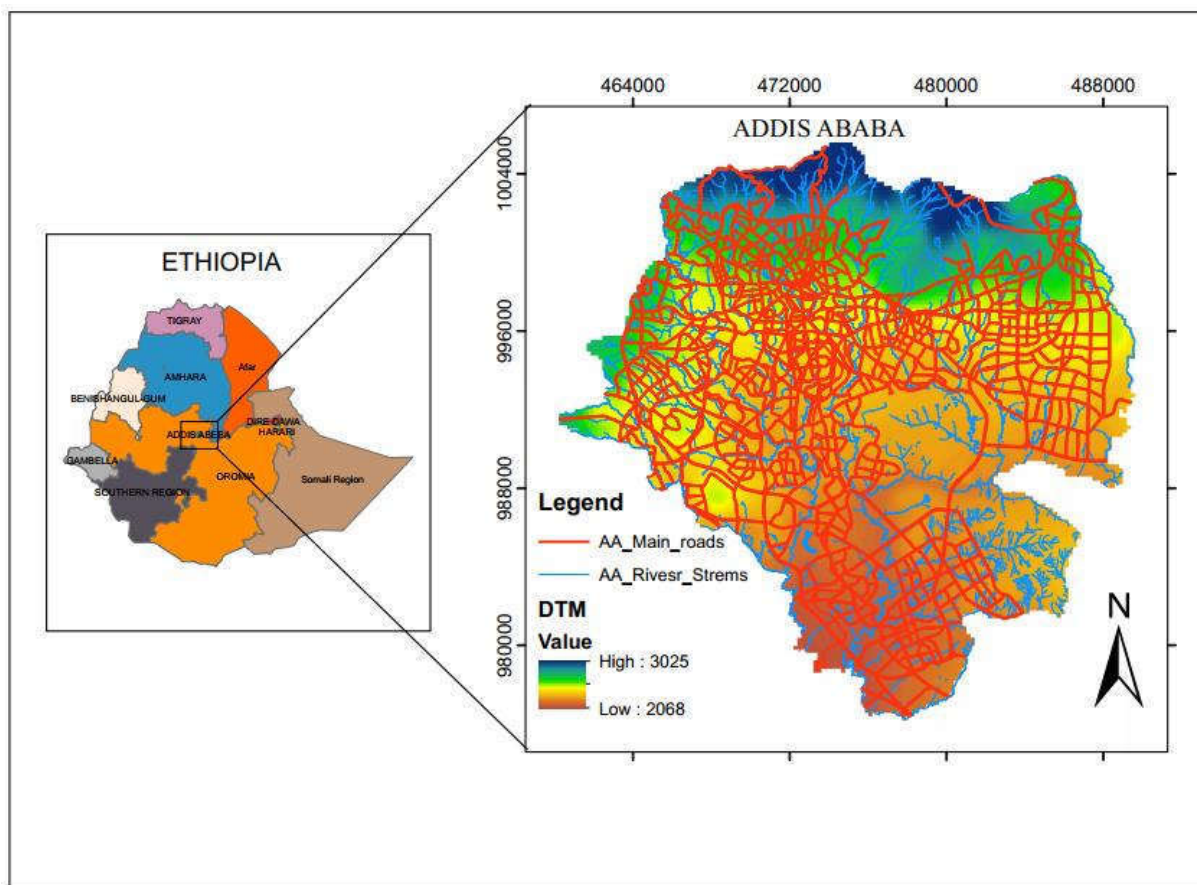


Figure 2. Location Map of Addis Ababa study area (<https://earthexplorer.usgs.gov> and addis ababa city administration)

### 3.2-Data

This research uses four relevant data, namely the Landsat image of the year 1992,2002,2014, and 2021, Digital elevation Model, soil map and Rainfall. The Landsat imager and DEM were obtained from USGS (<https://earthexplorer.usgs.gov>) , soil map and rainfall data are obtained from fao(<https://www.fao.org>) and CHRS (Center for Hydrometeorology and Remote Sensing) (<https://chrsdata.eng.uci.edu>) respectively.

#### 3.2.1 Landsat image

Satellite images are an important data to monitor LULC with remote sensing (Coppin et al.1996) Landsat imagery was used to determine LULC change, while dates were selected based on data quality, data availability (Table 1). Most researchers to classify LULC changeover the last three or four decades at every ten years according this study classified the study area over the last four decades at every ten years. Four Landsat imageries were acquired for the years 1992, 2002, 2014 and 2021 from the USGS. The software packages, ERDAS Imagine 2015 and Arc GIS 10.8 were employed at various stages of analysis.

Table 1. Data Source(<https://earthexplorer.usgs.gov>)

Satellite	Sensor	Path/Row	Date
LANDSAT-5	TM	168/054	1992-04-11
LANDSAT-5	TM	168/054	2002-02-02
LANDSAT-8	OLI_TIRS	168/054	2014-01-18
LANDSAT-8	OLI_TIRS	168/054	2021-03-26

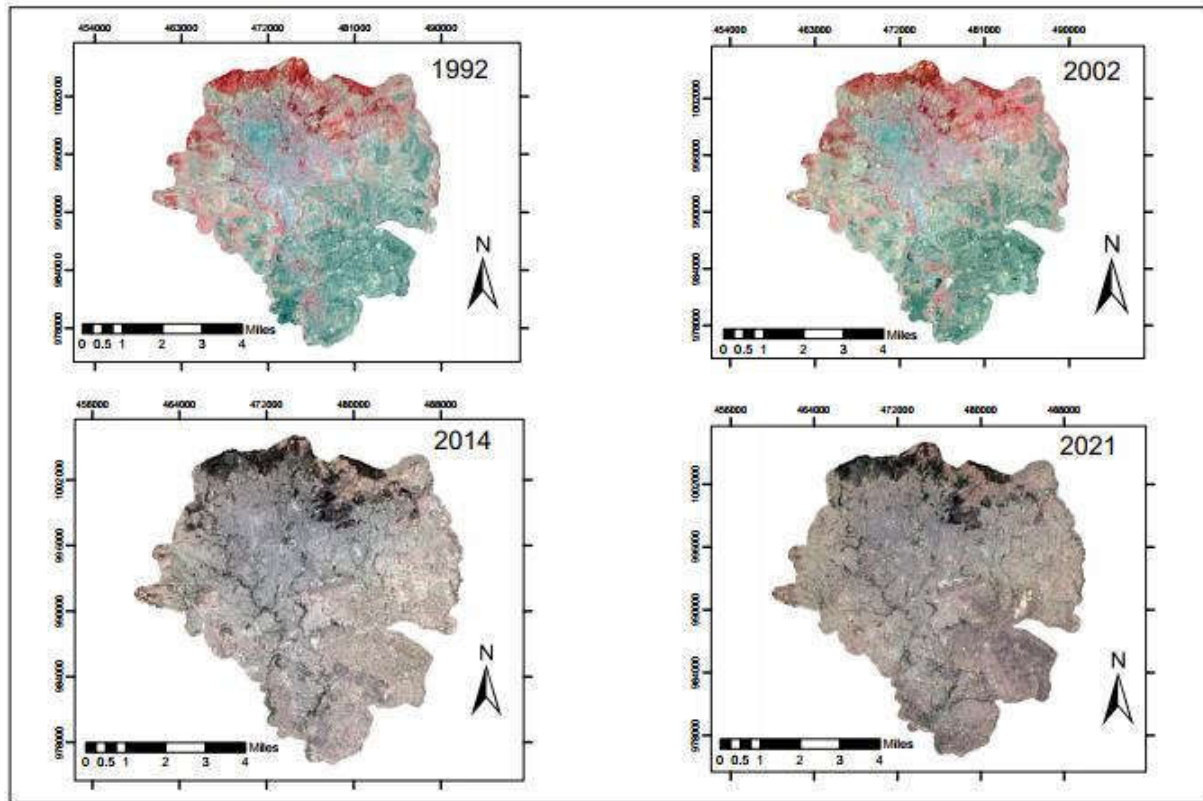


Figure 3.Landsat Imagery of the Study area(<https://earthexplorer.usgs.gov>)

### 3.2.2 Digital elevation model (DEM)

Digital Elevation Model (DEM) is the digital representation of the land surface elevation with respect to any reference datum and frequently used to refer to any digital representation of a topographic surface. DEM is the simplest form of digital representation of topography. DEMs are used to determine terrain attributes such as elevation at any point, slope and aspect. Terrain features like drainage basins and channel networks can also be identified from the DEM. The data obtained from USGS. In this research elevation, slope and drainage density are extracted from DEM.

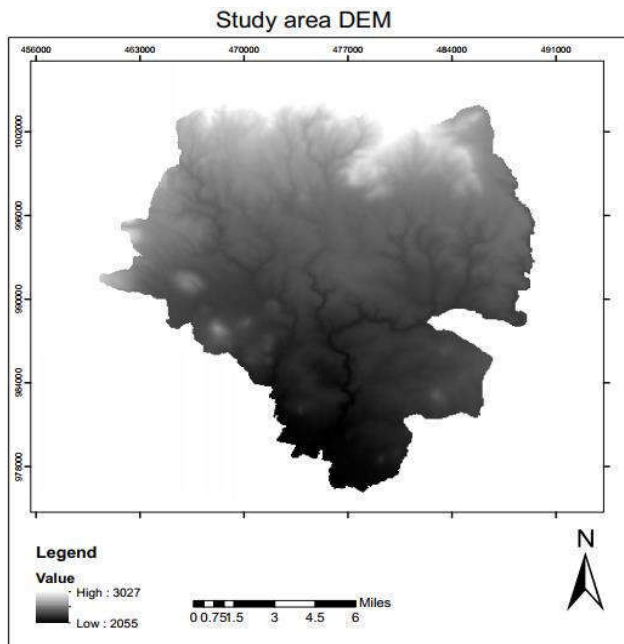


Figure 4. Digital elevation model (DEM) of the study area (<https://earthexplorer.usgs.gov>)

### 3.2.3 Soil

An important factor in determining flood hazard areas is the type of soil because it can increase or decrease the extent of flood events. Different soil types have different capacities to infiltrate water. The soil map of the study area was obtained from fao (<https://www.fao.org>) soil data base from Global Soil Data base classification.

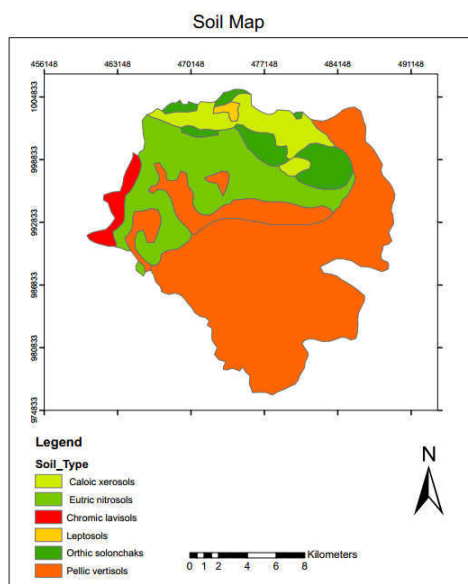


Figure 5. Soil Map of the study area (<https://www.fao.org>)

### 3.2.4 Rainfall

Rain fall is an important criterion for flood hazard because it can increase or decrease the amount of flood. Rain fall data obtained from CHRS (Center for Hydrometeorology and Remote Sensing).

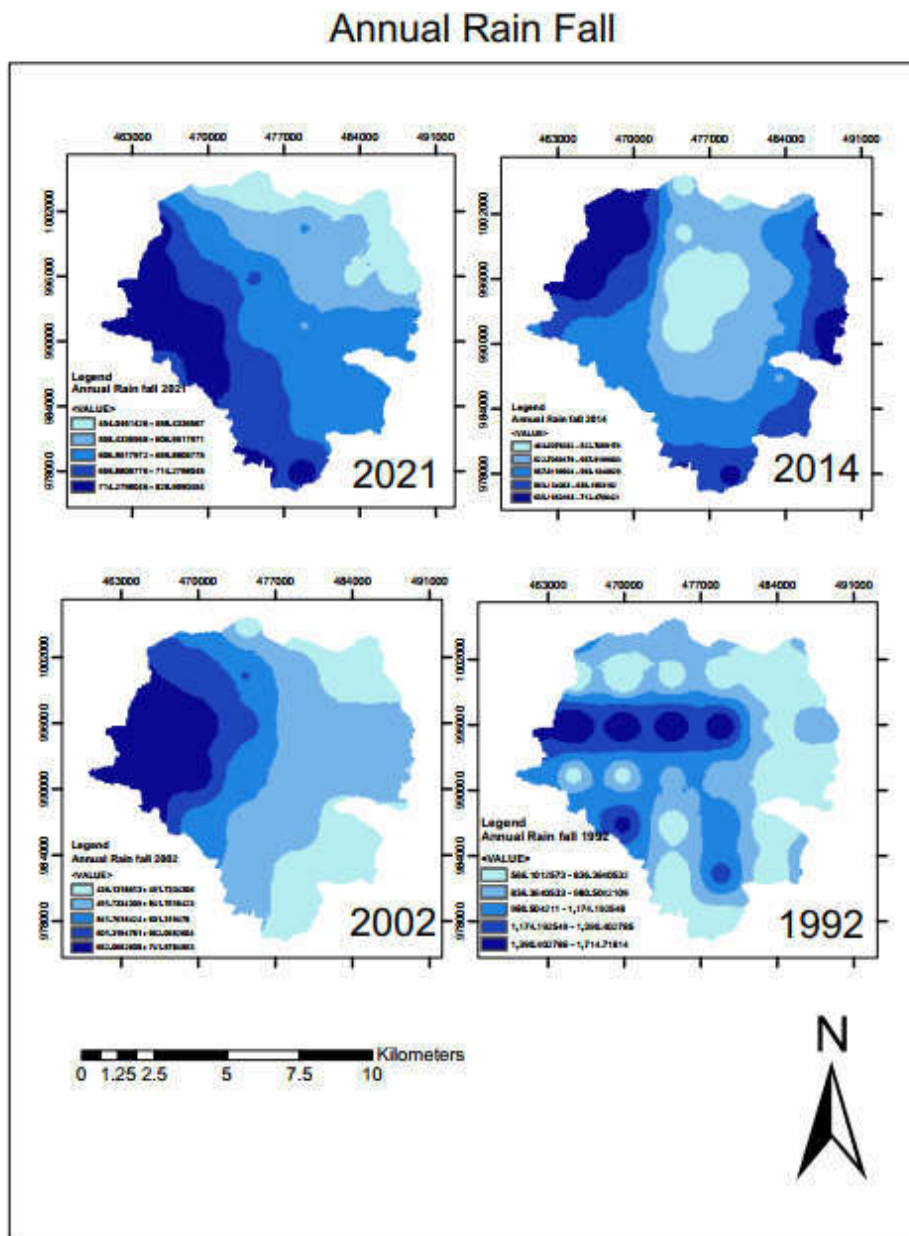


Figure 6. Rain fall map of the study area (<https://chrsdata.eng.uci.edu>)

### 3.3-Method

Spatial analysis in GIS environment will be applied to estimate flooding in which five relevant factors will be selected: Landsat image of 1992, 2002, 2014 and 2021, study area, Digital elevation model (DEM), Soil map and Rainfall. The influence of these factors was investigated by employing the sensitivity analysis and Analytic Hierarchy Process (AHP) method shown in Figure 7.

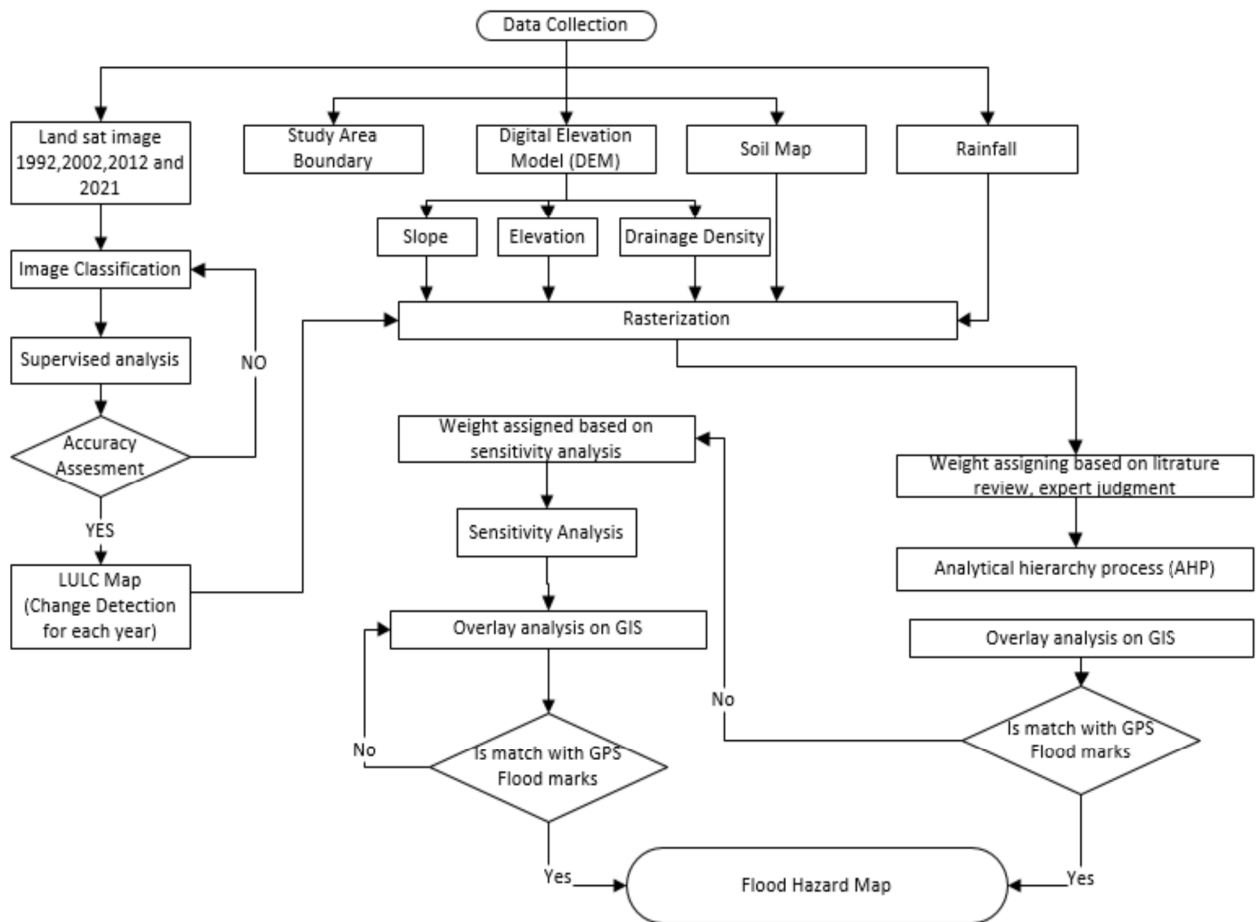


Figure 7. Methodology flow chart

#### 3.3.1 land use land cover change detection

##### 3.3.1.1. Image classification

During remote-sensing classification, we must keep in mind many factors that make it a complicated task. The main steps involved in image classification are determining a suitable classification system, feature extraction, selecting good training samples, image pre-processing

and selection of appropriate classification method, post-classification processing, and finally assessing the overall accuracy (Nath et al., 2014). In Most literature for LULC change detection analysis Agriculture, Barren Land, built up area, Forest and Water Bodies are common. According to this , To make change detection analysis and evaluation easier, the study area's various LULC classes were divided into five categories. The LULC classification includes Agriculture, Barren Land, built up area, Forest and Water Bodies.

Table 2. Image Classification Details (Vivekananda et al., 2021)

Agriculture	land Areas characterized by a high density of grasses, herbs, and crops, including parks and regularly tilled, planted croplands.
Barren land	This category includes land without crops, land with barren rock, and sand areas along rivers/stream beaches
Built-up	Land covered by concrete, including low-, medium, and high-density road networks; residential, industrial, and commercial buildings; educational institutes; transportation; open-roof concrete structures; other human-made structures; and solid waste landfills.
Forest	Land characterized by relatively sparse forest vegetation
Water Bodies	Areas covered by water, including rivers, reservoirs, ponds, lakes, and streams.

For image classification of the study area the following procedures were applied .

### I. Preprocessing

Preprocessing of image including Radiometric correction and geometric correction were applied, which is selecting appropriate map projection registration (simple point-to-point match of an image to another image or map) and rectification (correcting an image to a specific map projection) for the study area.

### II. Perform image classification.

Two major types of classification techniques: Supervised and Unsupervised. Land cover classification from remote sensing (RS) images is generally performed by using supervised classification techniques. This technique requires the availability of labelled samples for training the supervised algorithm. During training samples, the amounts are very crucial for obtaining accurate classification maps (Nath et al., 2014). in this study supervised classification techniques is used for the study area.

### **Land use/Landcover (LULC) Classification: Supervised**

Supervised classification is the technique most often used for quantitatively analyzing remote sensing image data. The supervised classification was applied after defined area of interest (AOI) which is called training classes. More than one training area was used to represent a particular class. The training sites were selected in agreement with the Landsat Image. The basic sequence operation followed on supervised classification.

**Defining of Training Sites:** The first step in undertaking a supervised classification is to define the areas that will be used as training sites for each land cover class. This is usually done by using the on-screen digitized features. The created features are called Area of Interest (AOI). The selection of the training sites was based on those areas clearly identified in all sources of images. In this study

**Extraction of Signatures:** After the training site (AOI) being digitized, the next step was to create statistical characterizations of each information. These are called Signatures editors in ERDAS Imagine 2015. In this step, the goal was to create a signal (SIG) file for every informational class. The SIG files contain a variety of information about the land cover classes described. After the entire signature have been created, then the SIG file saved as dialog. In supervised classification techniques many algorithms like Maximum Likelihood, Minimum Distance, and Parallelepiped classification etc. (Al-doski et al., 2013). In this research I used maximum likelihood algorithms because this algorithm is one of the most widely used classifiers in the remote sensing. In this method, a pixel is assigned to the class for which it has maximum likelihood of membership. This classification algorithm uses training data to estimate means and variances of the classes, which are then used to estimate probabilities of pixels to belong to different classes. Maximum likelihood classification considers not only mean or average values in assigning classification but also the variability of brightness values in each class around the mean. It is the most powerful of the classification algorithms as long as accurate training data is provided and certain assumptions regarding the distributions of classes are valid (Hull, 2021). For the study area A minimum of fifteen signature were used for each LULC type.

### **III. Post processing**

Completing geometric correction & filtering and classification decorating and accuracy assessment compare classification results of the study area with the google earth is applied .

#### **Accuracy Assessment**

One of the most important final steps at classification process is accuracy assessment. An accuracy assessment of a classified image gives the quality of information that can be obtained from remotely sensed data. The Accuracy assessment is performed by comparing a map produced from remotely sensed data with google earth. Overall accuracy for a particular classified image/map is

then calculated by dividing the sum of the entries that form the major diagonal (i.e., the number of correct classifications) by the total number of samples taken (Story & Congalton, 1986). After image is classified, generating a set of 100 random points (Tilahun, 2015) and A total of 85 random points were used for the validation and accuracy of the classification results (Islami et al., 2022) and both have a good result according to this A total of 100 point (for built up 30 points ,for barren land and agriculture 25 points for each and for forest and water bodies 10 point for each ) were created for each years in the classified image of the study area. In this research, overall classification accuracy and overall, Kappa statistic are computed and overall accuracy, user's and producer's accuracies, and kappa coefficients were used to summarize the information and to obtaining accuracy measures.

Table 3. Rating Criteria of Kappa statistics (Islami et al., 2022)

No	Kappa statistics	Strength of agreement
1	<0	Poor
2	0.00 – 0.20	Slight
3	0.21 – 0.40	Fair
4	0.41 – 0.60	Moderate
5	0.61 – 0.80	Substantial
6	0.81 – 1.00	Almost perfect

### 3.3.2 Flood hazard Map

A flood hazard map is a crucial tool for determining a flood-prone area's vulnerability. The flood hazard maps aim is to minimize the damage in case of flood by giving information to the residents in advance (Shidawara, 1999). This research focuses on evaluating flood hazard zone in Addis Ababa City. For the estimation of flood risk zones in which six relevant physical factors have been selected namely, rainfall amount, slope, elevation, drainage density, land use land cover and soil type based on permeability. These factors were selected as of literature review made which were conducted by most research papers. The influence of these factors was investigated employing sensitivity analysis method and Analytic Hierarchy Process (AHP) method Figure 7.

#### 3.3.2.1 Analytical Hierarchy Process (AHP)

In the 1970s, Thomas L. Saaty developed the analytic hierarchy process (AHP) technique, which constructs a decision-making problem in various hierarchies as goal, criteria, sub-criteria, and decision alternatives (Sipahi & Timor, 2010). In this study, the factors for flood generating's are filled in matrix using ground truth, topographic setup, area of knowledge, field specialist judgment and literature review in subject matter and the pairwise comparison matrix employed. After pairwise comparison normalizing the matrix and consistency ratio is done.

In this study, ArcGIS with spatial analysis toolbox modules is used coupling with an excel spread sheets for the analysis for the computations of weights and ratings for each flood hazard producing factors.

Table 4. Fundamental AHP Judgment Scale with integers 1 to 9 and their definition(saaty,1980)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
1.1-1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

In this study, the factors for flood generating’s filled and developed in matrix using ground truth, topographic setup, area of knowledge, field specialist judgment and literature review in subject matter that represented .The pairwise comparison matrix employed using 6 x 6 matrix, where diagonal elements are equal to 1. This implies. The values of each row are compared with each column to define the relative importance to obtain rating score. LULC is moderate importance from rainfall and assign the value 3. The inverse of pairwise comparison matrix is 1/3 for LULC that show in the Table 5

Table 5.Pairwise Comparison Matrix (Judgment Matrix)

Factors	Rain fall	Draiange	LULC	Soil type	slope	elevation
Rain fall	1	2	3	4	3	3
Draiange Density	1/2	1	3	3	4	4

LULC	1/3	1/3	1	4	3	3
Soil type	1/4	1/3	1/4	1	2	2
slope	1/3	1/4	1/3	1/2	1	1
elevation	1/3	1/4	1/3	1/2	1	1
Sum	2.75	4.17	7.92	13.00	14.00	14.00

Divided each element of the matrix by the column total by the total value of the column and calculated the average of the elements of each row.

Normalizing the matrix computed by dividing each element in every column divided by the sum of that column and criteria weight can be the average of each row in the normalizing matrix

Table 6. Normalizing the matrix and criteria Weight

Factors	Rain fall	Drairage	LULC	Soil type	slope	elevation	Weight
Rain fall	0.36	0.48	0.38	0.31	0.21	0.21	33%
DrairageDensity	0.18	0.24	0.38	0.23	0.29	0.29	27%
LULC	0.12	0.08	0.13	0.31	0.21	0.21	18%
Soil type	0.09	0.08	0.03	0.08	0.14	0.14	9%
slope	0.12	0.06	0.04	0.04	0.07	0.07	7%
elevation	0.12	0.06	0.04	0.04	0.07	0.07	7%

Individual judgments never be agreed perfectly. In order to remove or minimize any subjectivity, during prioritization rate importance of one criteria against another criterion it is important to compute consistency ratio (CR) and computed using the formula by (Eq2). The Consistency Ratio (CR) tells the decision-maker how consistent he/she has been when making the pair-wise comparisons. A higher number means the decision-maker has been less consistent,

whereas a lower number means the decision-maker has been more consistent. If the Consistency Ratio (CR) < 0.10, the decision-maker's pair-wise comparisons are relatively consistent. If the Consistency Ratio (CR) > 0.10, the decision-maker should seriously consider re-evaluating his/her pair-wise comparisons – the source(s) of inconsistency must be identified and resolved and the analysis re-done (Kunz, 2010).

To compute the CR, first, the Consistency Index (CI) from the pairwise comparison matrix of all the parameters

$$\text{Consistency index (CI)} = \frac{\lambda_{\max} - n}{n(n-1)} \dots \dots \dots \text{Eq 1}$$

n is the number of factors considered which is 6 and lamdeda ( $\lambda_{max}$ ) is the average of consistency vector calculated in excel spreadsheets and the values is 6.36 and the consistency index is computed in the above equation which is 0.07.

The CR has been computed using Eq2 below

$$CR=CI/RI \dots\dots\dots Eq 2$$

where RI is the random index whose value depends on the number of factors compared (n=6), provided by(Saaty, 2006) inTable 7below.

Table 7.Random index values(Saaty, 2006)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Hence, the Consistency ratio (CR) has been computed using the above equation gives a value of 0.058. Finally, the calculated consistency ratio is that is lower than the threshold 0.1, so that the weights' consistency is confirmed and accepted as required by the AHP principles.

Table 8.Weight of factors

Factors	Weight
Rain fall	32
Drainage Density	27
LULC	18
Soil type	9
slope	7
elevation	7

After calculating the relative importance and determining the weight of each factor in the hierarchy,the vulnerability is calculated using the following formula:

$$\text{Vulnerability} = 0.32 \text{ Rainfall} + 0.27 \text{ Drainage Density} + 0.18 \text{ LULC} + 0.09 \text{ Soil type} + 0.07 \text{ Slope} + 0.07 \text{ Elevation.}$$

### 3.3.2.2. sensitivity analysis

Sensitivity analysis methods have been applied in various fields. After assessing how important each criterion is, the decision-maker is more equipped to make choices. To put it another way, the decision makers must explain how responsive the real ranking of the alternatives is to changes in the existing weights of the choice criteria(Kang et al., 2013). Sensitivity analysis is done to

determine the relative importance of the mention flood generating factors. Initially equal weight has been given for all the six factors (rainfall amount, slope, elevation, river density, land use and soil type based on permeability and base case scenario was performed. Then, flood vulnerability indexes of different scenarios, which turn off the weight of individual factor at a time, were determined. Consequently, the produced flood prone areas were compared against base case scenario and weight of the factors are determined.

Initially equal weight has been given for all the six factors (rainfall amount, slope, elevation, river density, land use and soil type based on permeability and base case scenario was performed (scenario 1).

Table 9. Rating of factor for sensitivity analysis for scenario\_1

Scenario	Factor	Weight(%)
Scenario 1	Slope	16.67
	Elevation	16.67
	Drainage Density	16.67
	Rain Fall	16.67
	LULC	16.67
	Soil	16.67

Each weighted value of flood generating factor is 16.67% (i.e the sum of all factor should be considered 100) and using a weighted overlay spatial analysis in ArcGIS 10.8 flood hazard map were created as shown in the Figure 16.

After the base scenario(scenario 1), other six scenarios from scenario 2 to scenario 7 have been performed by turn off the weight of individual factor at a time for scenario 2 by turn off slope, for scenario 3 by turn off elevation, for scenario 4 by turn off drainage density, for scenario 5 by turn off rain fall for scenario 6 by turn of LULC and for scenario 7 by turn off soil as shown in the Table 10 below and observing its effect and sensitivity in the newly created six flood hazard map in the Figure 17.

Table 10. Rating of factor for sensitivity analysis of different scenarios

Scenario	Factor	Weight (%)	Scenario	Factor	Weight(%)
	Elevation	20		Slope	20
	Drainage Density	20		Elevation	20
Scenario 2	Rain Fall	20	Scenario 5	Drainage Density	20
	LULC	20		LULC	20
	Soil	20		Soil	20
	Slope	20		Slope	20
	Drainage Density	20		Elevation	20
Scenario 3	Rain Fall	20	Scenario 6	Drainage Density	20
	LULC	20		Rain Fall	20
	Soil	20		Soil	20
	Slope	20		Slope	20
	Elevation	20		Elevation	20
Scenario 4	Rain Fall	20	Scenario 7	Drainage Density	20
	LULC	20		Rain Fall	20
	Soil	20		LULC	20

## CHAPTER FOUR

### 4. RESULT AND DISCUSSION

In this chapter, the result of the paper is described in detail. Accordingly the result discussion is categorized in to two. The first category describes the results of LULC change and flood hazard map and second category focuses on the discussion of the results of the LULC and flood hazard map.

#### 4.1 Result

##### 4.1.1 Land use Land Cover change

The classified images have been summarized in the Table 15. The trend of LULC change from 1992-2021 based on five classes with a proportionate coverage area for each. Moreover, the spatial representation of LULC types for 1992,2002,2014 and 2021 is shown in Figure 8

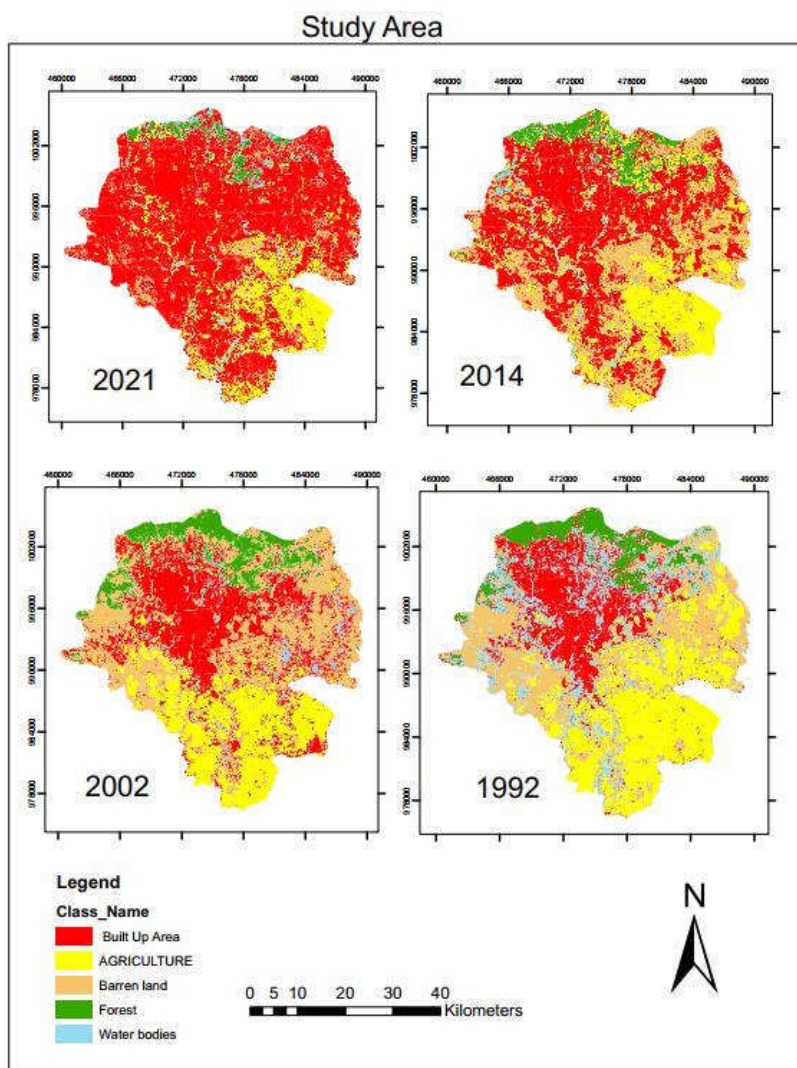


Figure 8. The Classified image of the study area

#### 4.1.2 Flood hazard Map

Figure 7 depicts the process used to create the flood hazard area maps. For the sensitivity analysis case, using weighted overlay spatial analysis techniques, each flood hazard generating element was initially given an equal weight before being used to create a flood hazard map in ArcGIS 10.8. subsequently examines the impact of one element being removed from the analysis by analyzing its sensitivity and viewing the newly created flood hazard map. While using AHP methodologies, Prior to calculating the mutual (pairwise) interaction ratios, all the elements that contribute to the risk of flooding will be identified. Hence The flood hazard map will be created using these weights. Details of the analysis were provided in each relevant section. For the analysis for the computations of weights and ratings for each element causing flood hazards, ArcGIS 10.8 with the spatial analysis toolbox modules will be utilized in conjunction with an excel spreadshee

##### 4.1.2.1 Flood hazard factor

In the study area, slope, elevation, rainfall, drainage density, land use, land cover, and soil type are the main flood hazard generating factors taken into account.. These flood hazard generating factors were first converted in to raster form. According to literature reviews, the raster layers have been further categorized depending on their potential to flood the area. at. Hence each factor was reclassified using methods of an equal interval of five classes using Spatial Analysis reclassification techniques in ArcGIS environments. The classification and rating values for each element taken into consideration in this study are shown in Table 11 below.

Table 11. classification and rating values for flood hazard

Classifications	Rate
Very Low	1
Low	2
Moderate	3
High	4
Very High	5

##### i. Elevation

Figure 9 shown. The reclassification produced using a natural break (Jenks) with classes of five. The lower the elevation value is the very highly affected by flood and then rating to class 5 which is very high hazard area, which is lies in between 2055 to 2192m. Following the high hazard class, there was a class high (2192- 2316m) rating 4, class moderate (2316-2462m) ratio 3, class low (2462-2662 m) rating 2 and class very low rating 1 (2662-3027 m). The classification rate is show in Table 13.

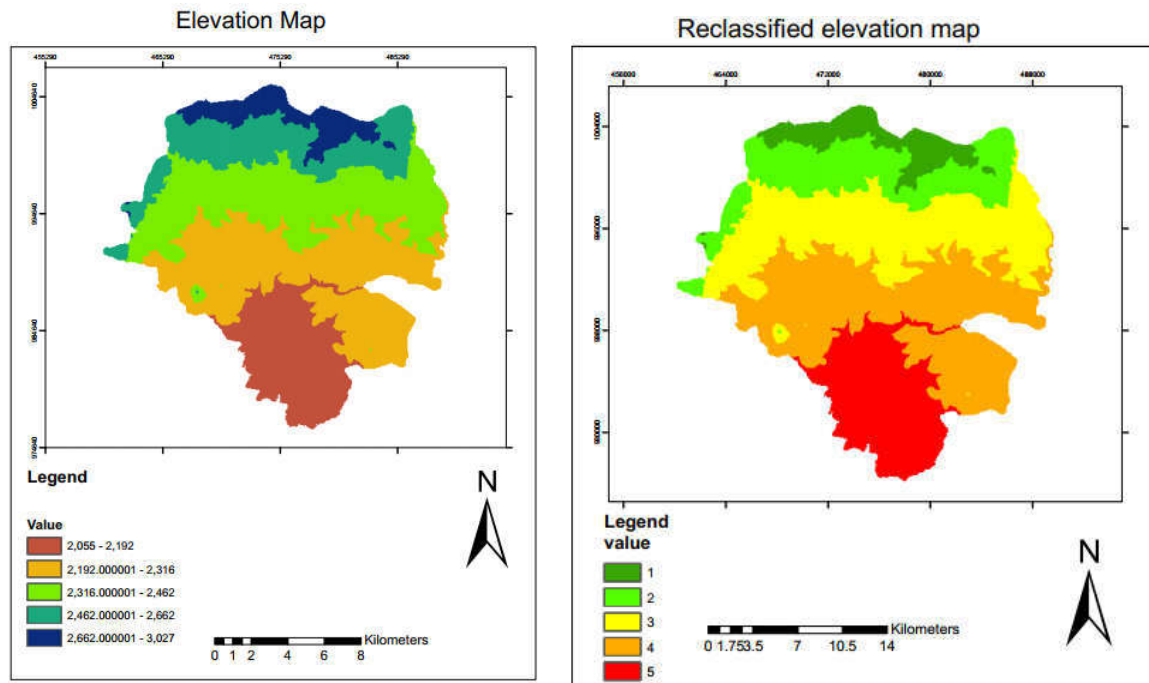


Figure 9.Elevation Map

## ii. Land use Land Cover

The Land Use Land Cover (LULC) of the study area play a significant role in the movement of flood water by hindering, slowing or accelerating on the surface flow. The LULC of the studied region has an impact on infiltration rates, how surface and groundwater interact, and debris movement. The LULC was classified in five classes as shown in Figure 10.Land use Land cover MapThus, while forest covers favor infiltration and reduce flooding, it's given as very low flood affected areas and very lower rating of 1, Agricultural area low flood affected area and low rating of 2, barren land moderate flood affected area and rating 3 , built up area high flood affected area and rating 4 and water bodies very high flood affected area and rating 5 as shown in the Table 13.

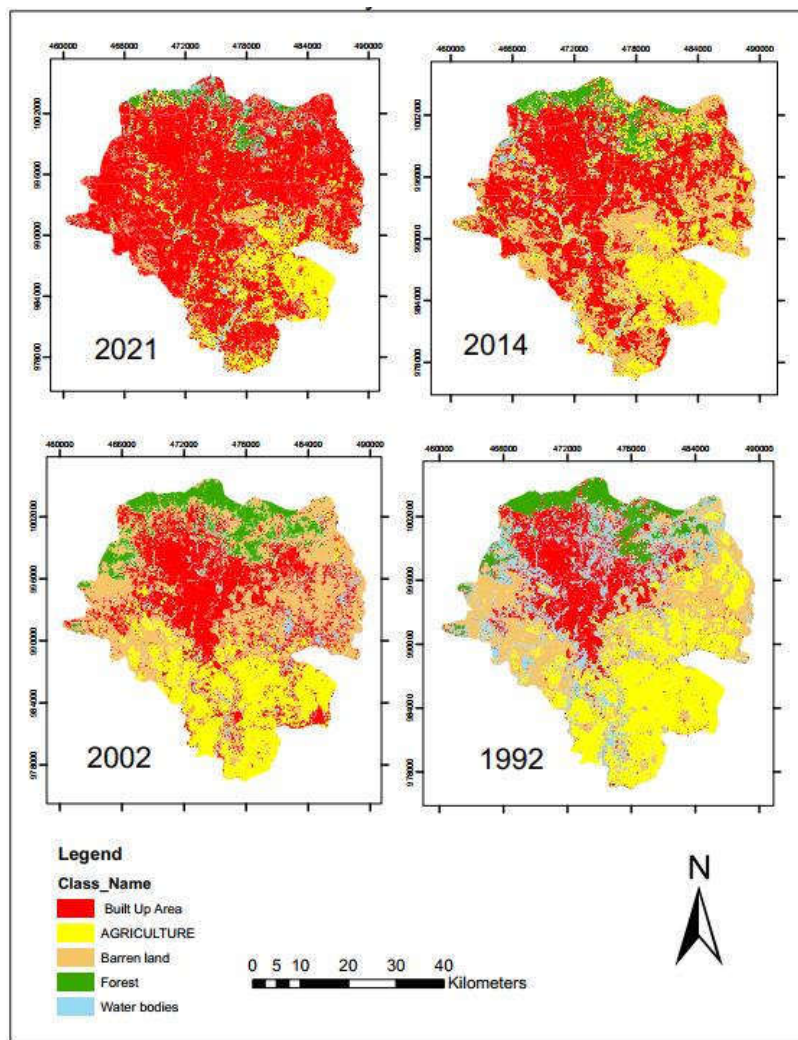


Figure 10. Land use Land cover Map

### iii. Rainfall

The Rainfall in the year 2021, raster layer was classified into five classes. In the classification process of the study area with higher rainfall, is very highly affected by flood and then rating as class 5, which(714-828mm/year).Following the very high hazard class, there is a class high (659-714mm/year) rating as class 4, moderate (606-659 mm/year) rating as class 3, low (558-606 mm/year) rating as class 2 and very low rating as class 1 (454-558mm/year).In the year 2014 ,very highly affected by flood and then rating as class 5, which(635-712mm/year).Following the very high hazard class, there is a class high (593-635mm/year) rating as class 4, moderate (557-593 mm/year) rating as class 3, low (522-557 mm/year) rating as class 2 and very low rating as class 1 (463-522mm/year). In the year 2002, very highly affected by flood and then rating as class 5, which(662-741mm/year). Following the very high hazard class, there is a class high (601-662mm/year) rating as class 4, moderate (541-601mm/year) rating as class 3, low (491-541

mm/year) rating as class 2 and very low rating as class 1 (438-491mm/year). In the year 1992, very highly affected by flood and then rating as class 5, which(1390-1741mm/year). Following the very high hazard class, there is a class high (1174-1390mm/year) rating as class 4, moderate (980-1174 mm/year) rating as class 3, low (836-980mm/year) rating as class 2 and very low rating as class 1 (566-836mm/year).

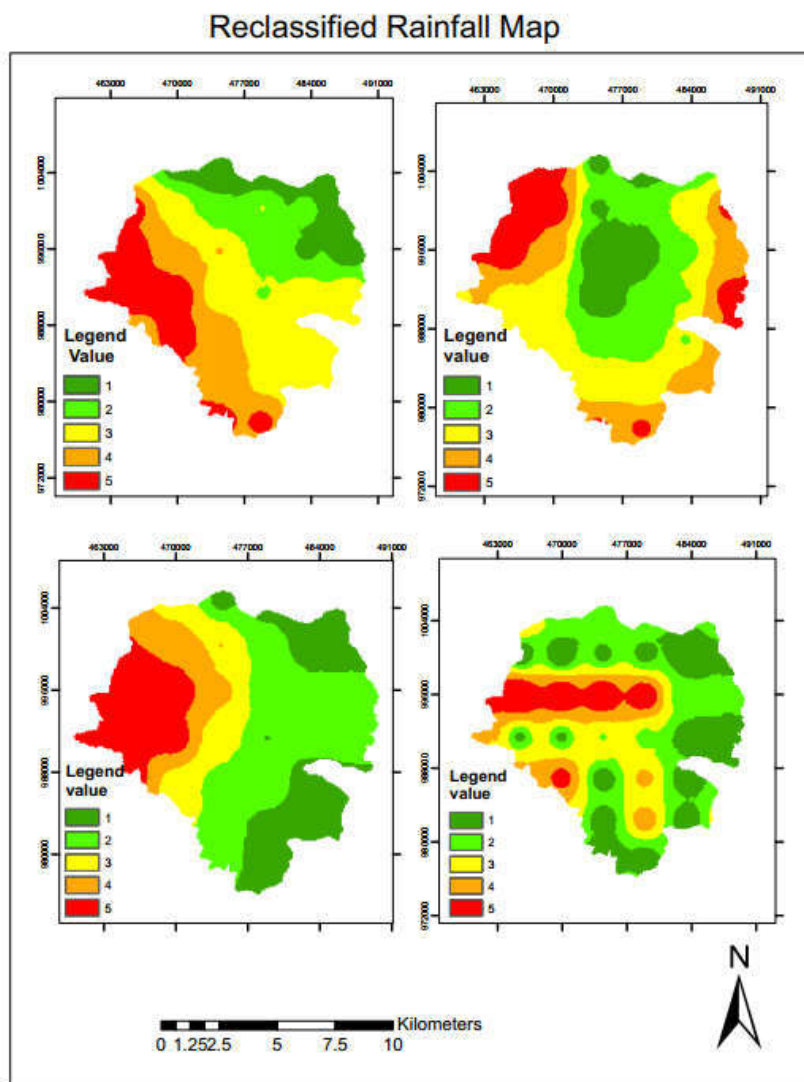


Figure 11. Rain fall map of the year 1992,2002,2014 and 2021

#### iv. Drainage Density

The drainage density is calculated by dividing the sum of the lengths of all the rivers and streams in a drainage basin by its overall area. The DEM was used to compute the drainage density using

the spatial analyst extension for extracting flow accumulations. Hence a stream polyline features was created from the flow accumulation

To determine drainage density area from stream polyline features in a GIS system, kernel density was used. The drainage density layer was classified in five classes as shown in Figure 12. In the classification process an area with a higher drainage density is very highly affected by flood and then classified as very high hazardous area and rated 5, whereas an area having smaller drainage density the minimum area to be affected and rank as very Low. The Table 13 shows the detail classification class and ranking of drainage density.

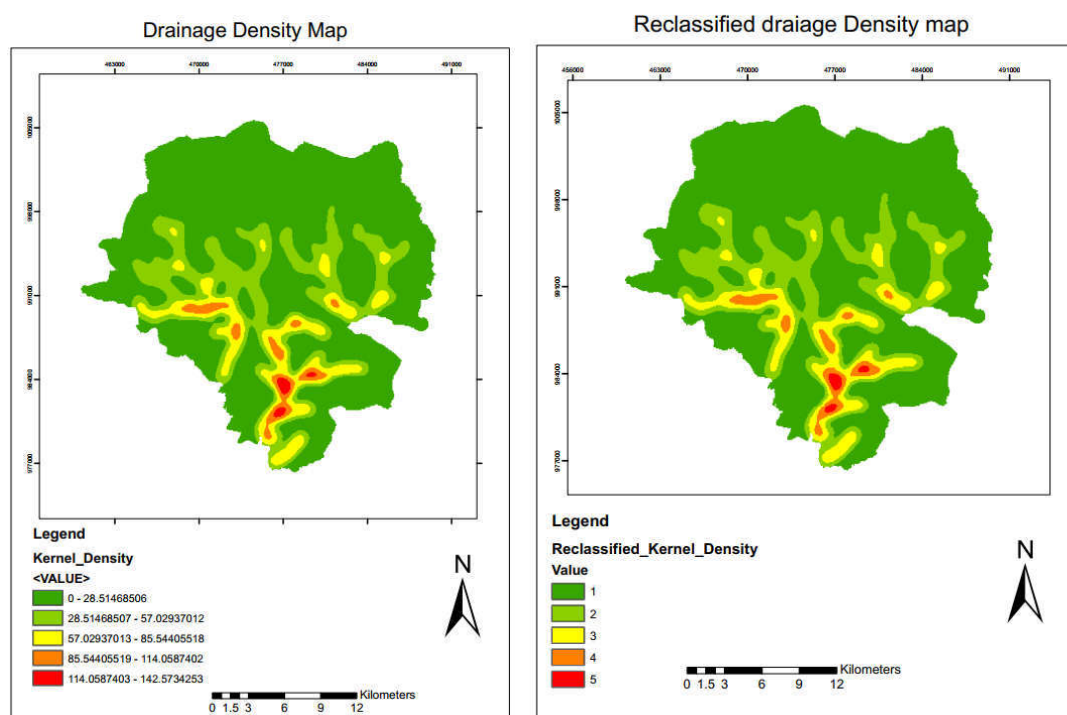


Figure 12. drainage Density map

#### v. Slope

The slope is computed from DEM and reclassified in to five classes that shown in the Figure 13. Slope affects the amount of surface runoff and infiltration because water flows from higher to lower altitudes. This is because water moves quickly in areas with steep topography and is less affected by flooding, but water moves slowly in areas with flat terrain and might cause flooding hazards. Naturally, low slope and low elevation have been assigned the highest rating of 5, as flood prone areas of Table 13

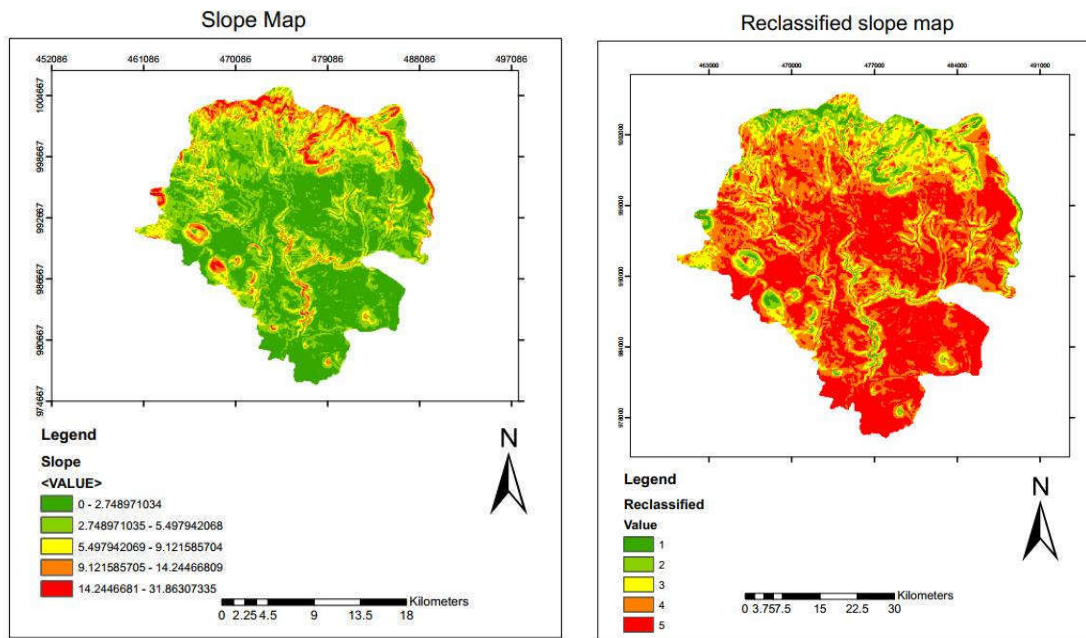


Figure 13.Slope map

vi. Soil

Soils are a key factor in determining flood risk since they have the potential to change the size of flood events. Different soil type has different capacity to infiltrate water. The Figure 14 shows reclassification.

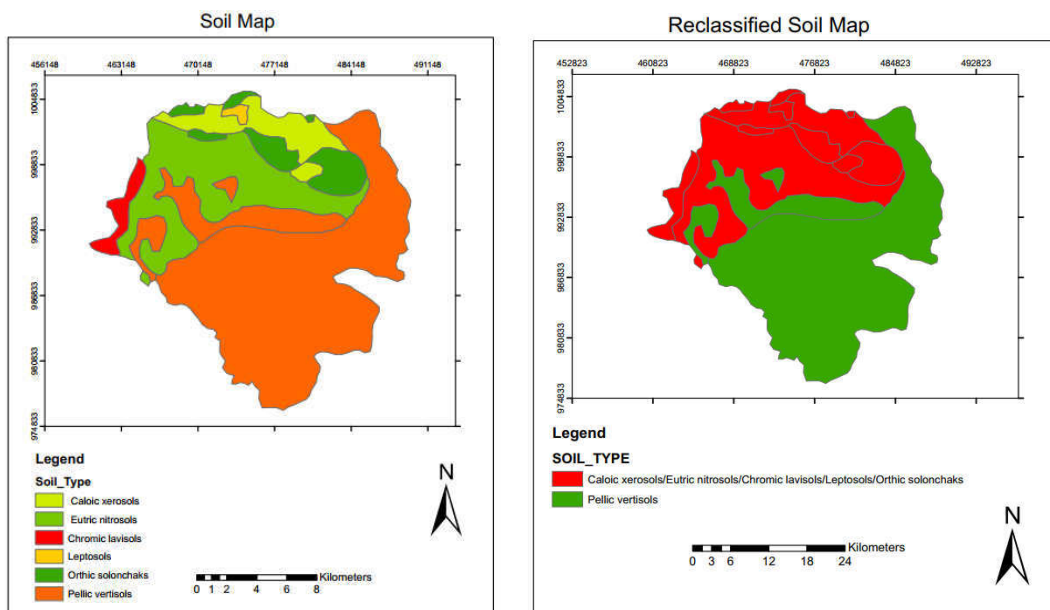


Figure 14.soil map

Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration. Permeability and infiltration are the principal data required to classify soils Groups (HSG). Based on infiltration rates, the Soil Conservation Service (SCS) has divided soils into four hydrologic soil groups as follows(Manual & Website, 2013):

Group A: Sand, loamy sand or sandy loam. Soils having a low runoff potential due to high infiltration rates. These soils primarily consist of deep, Well-drained sands and gravels.

Group B: Silt loam, or loam. Soils having a moderately low runoff potential due to moderate infiltration rates. These soils primarily consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C: Sandy clay loam. Soils having a moderately high runoff potential due to slow infiltration rates. These soils primarily consist of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.

Group D: Clay loam, silty clay loam, sandy clay, silty clay or clay. Soils having a high runoff potential due to very slow infiltration rates. These soils primarily consist of clays with high swelling potential, soils with permanently-high water tables, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

The study area soils were categorized as shown in Table 12

Table 12. Hydrologic soil group of different soil type in Addis Ababa(Manual & Website, 2013)

Soil Types	Hydrologic Soil Group (HSG)
Caloic xerosols	B
Eutric nitrosols	B
Chromic lavisols	B
Leptosols	B
Orthic solonchaks	B
Pellic vertisols	D

As a result of the aforementioned information, the soil factor's classification and rating as shown in the Table 13.

Table 13. Class and rating of each flood hazard generating factor

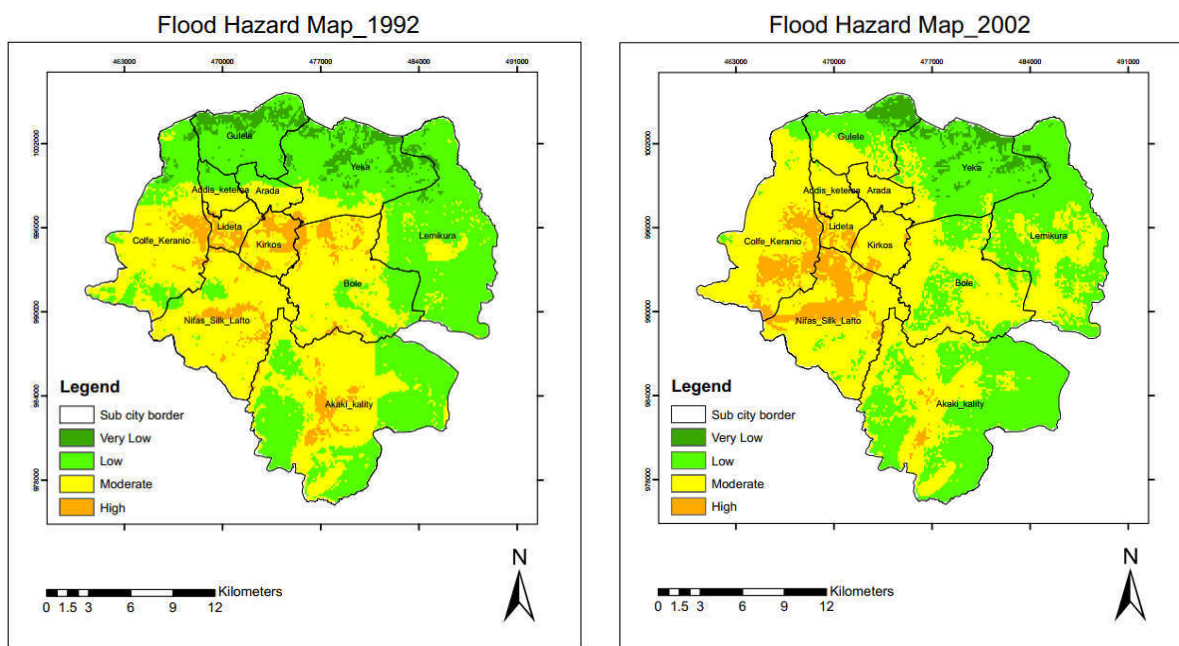
Factor	Class	Naming	Rating	Factor	Class	Naming	Rating
Slope	0 - 2.7	Very High	5	Rain Fall(2021)	454-558	Very Low	1
	2.7- 5.5	High	4		558-606	Low	2
	5.5 - 9.1	Moderate	3		606-659	Moderate	3
	9.1 - 14.2	Low	2		659-714	High	4
	14.2- 31.9	Very Low	1		714-828	Very High	5

## Evaluation of the impact of land use/ land cover changes on the floods of Addis Ababa city

Elevation	2055-2192	Very High	5	LULC	Forest	Very Low	1
	2192-2316	High	4		Agriculture	Low	2
	2316-2462	Moderate	3		Barren land	Moderate	3
	2462-2662	Low	2		Built Up	High	4
	2662-3027	Very Low	1		Water bodies	Very High	5
Drainage Density	0 - 10.36	Very Low	1	Soil	B	Low	2
	10.36 - 31.07	Low	2		D	High	4
	31.07 - 55.44	Moderate	3				
	55.44 - 84.68	High	4				
	84.68 - 155.35	Very High	5				

### 4.1.2.2 Flood Hazard Map by using Analytical Hierarchy Process

The factors for flood generating's are filled in matrix using ground truth, topographic setup, area of knowledge, field specialist judgment and literature review in subject matter and the pairwise comparison matrix employed. After pairwise comparison normalizing the matrix and consistency ratio is done. The weight of flood generating factor computed as described in Table 8. The flood map in the Figure 15. Showed that a high flood hazard has imposed by the flood in the Nifas silk lafto and Akaki Kaliti sub city of the study area. AHP result reveals that rainfall, drainage density and LULC have a high influence on flood occurrence



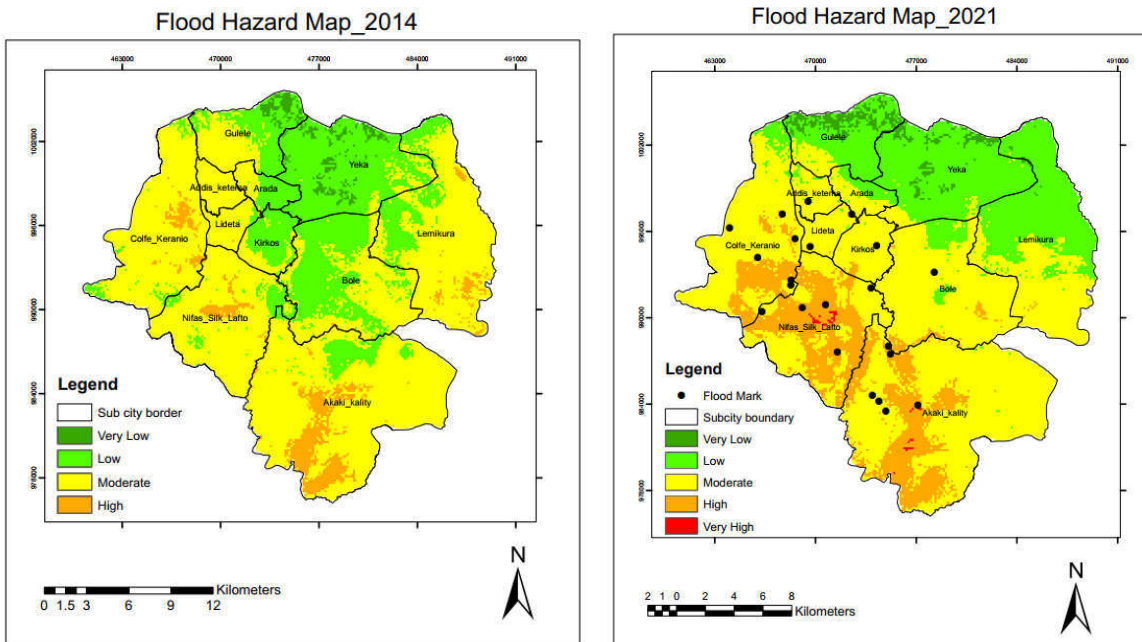


Figure 15. Flood hazard map developed using AHP method

#### 4.1.2.3 Flood hazard map by using Sensitivity Analysis

The AHP method was further validated with sensitivity analysis in the sensitivity analysis, all factors were initially considered as they are equally important for generating flood and have equal weight for six flood generating factors and base scenario (scenario\_1) flood hazard map developed that are shown in the Figure 16.

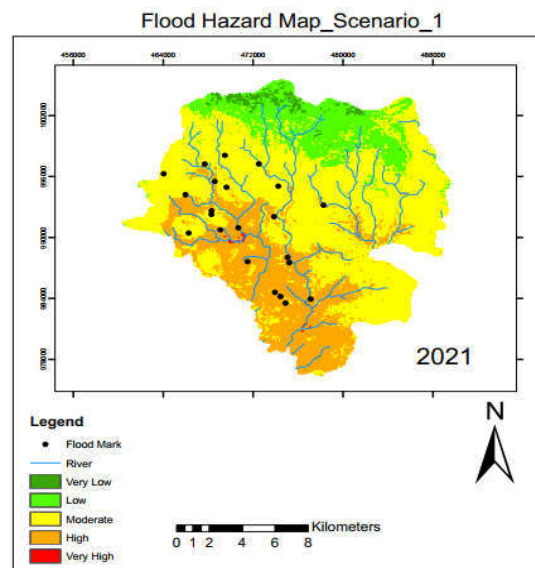
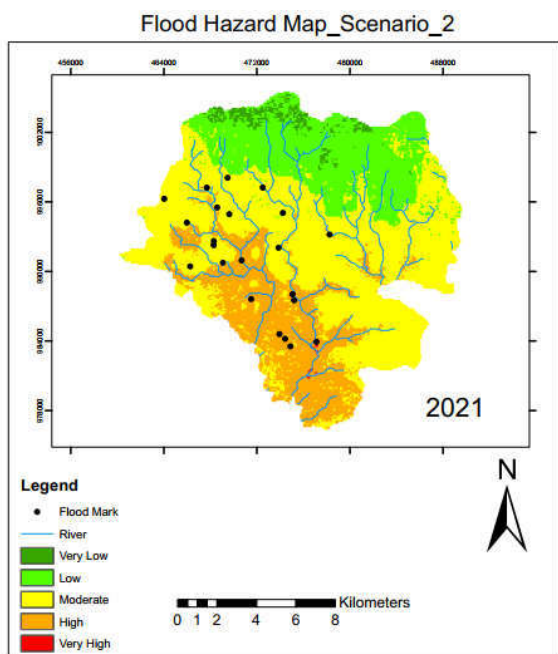
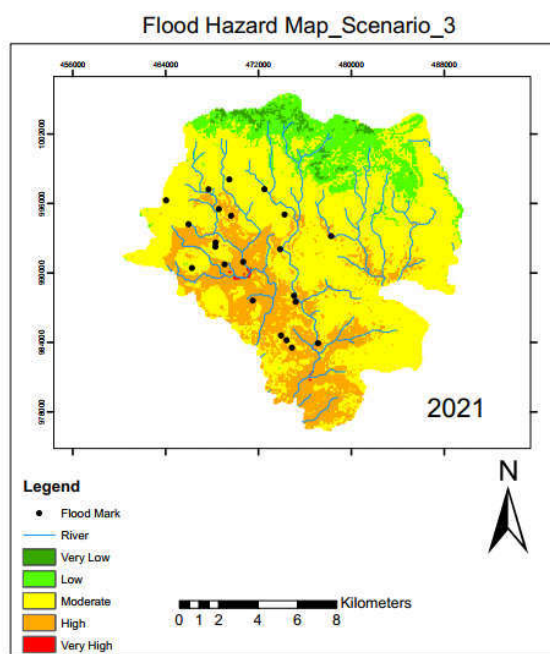


Figure 16. Flood hazard map for scenario 1

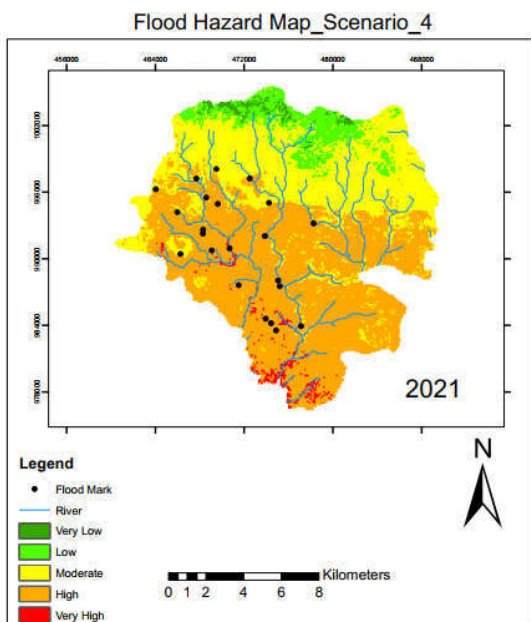
Additionally six scenarios were performed by turning of one factor at a time that shown in the Table 10 and flood hazard map for each scenario were developed and the flood hazard map are shown in Figure 17 below.



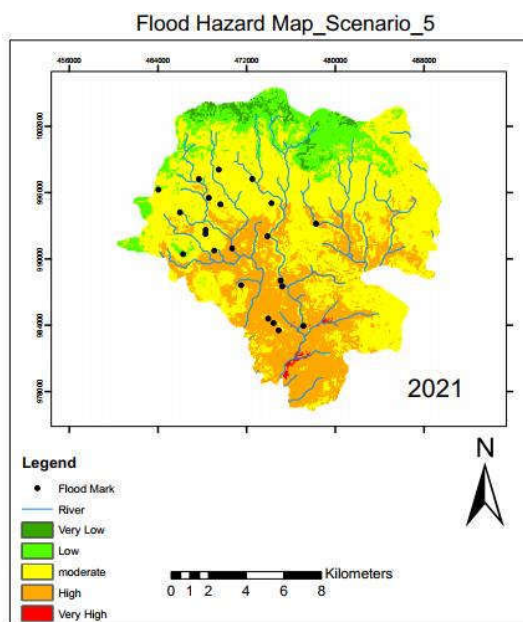
Scenario 2: without slope



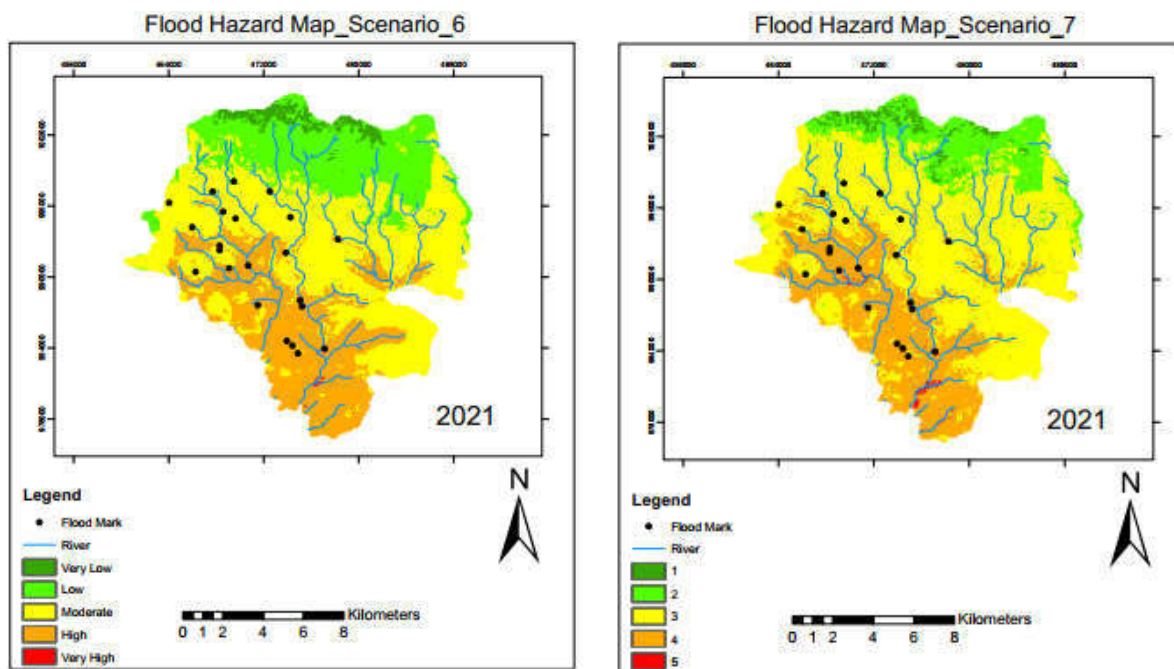
Scenario 3: without Elevation



Scenario 4: without Drainage Density



Scenario 5: without Rain fall



Scenario 6: without LULC

Scenario 7: without Soil

Figure 17. Flood hazard map for different scenario

From the sensitivity analysis performed from scenario 2 to scenario 7, an evaluation was done to see how each factor affected the other factors for developing flood hazard map. This helps to better understand the importance of each factor in identifying against the low impact factors for flooding. Since sensitivity analysis illuminates the subjective significance of the various factors taken into account as well as useful information regarding the influence of rating weighting values assigned to each factor. Moreover, in order to mitigate flood risk, identifying of the significant factors for flooding uses to select the type of measure to be employed as a mitigation measure for quick and emergency flood adaptation mechanism and extreme management purpose. According to scenario 2 to scenario 7 rainfall, Drainage density and LULC were reflected in the sensitivity analysis. In addition to this soil, slope and elevation less important for flood hazard generating.

After conducting the sensitivity analysis as described above the new rating value were made manually in iterative way such that the produced flood hazard mapping was validated against the flood mark taken from AAFERCPA (Addis Ababa fire emergency rescue control and prevention Authority).

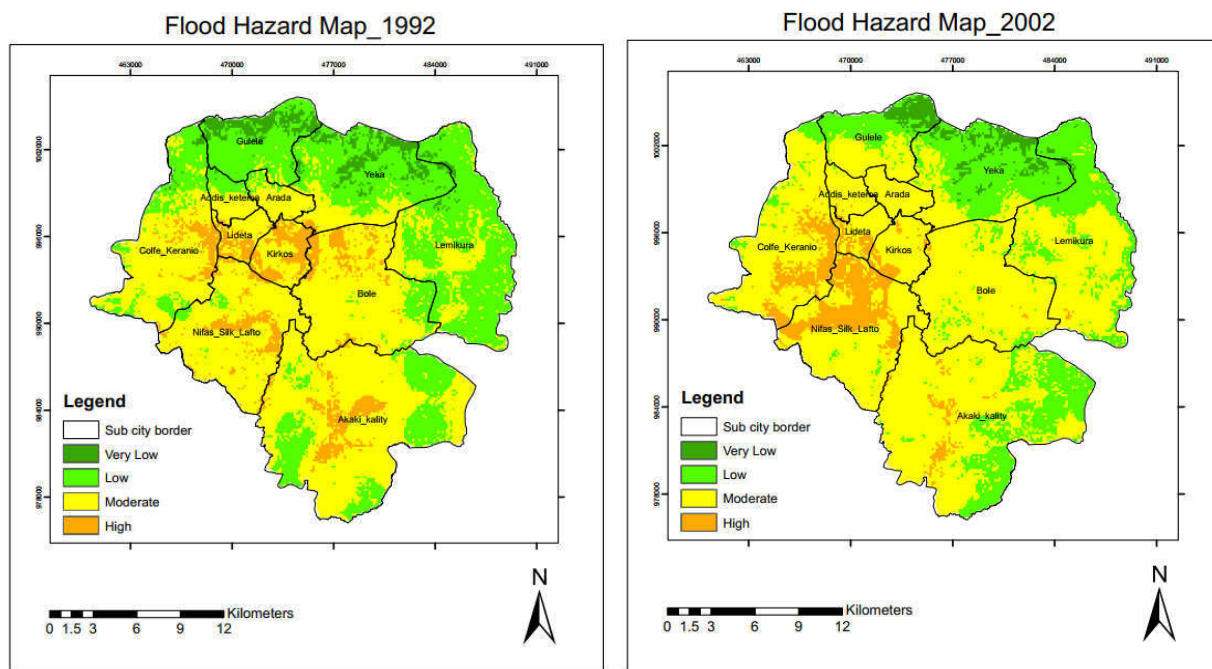
Hence as shown in the Table 14 below rain fall and drainage density significant impact for flood hazard generating followed by LULC in the study area.

Table 14. Weight for flood generating factor from sensitivity analysis

Factors	Weight
Rain fall	26
Drainage density	23
LULC	20
Soil type	7
slope	12
elevation	12

Thus, after the newly rating value from the sensitivity of the flood hazard generating factor, flood hazard map was created using the formula below and applying weighted overly techniques in spatial toolbox in ArcGIS 10.8 environment interface. Finally, the Figure 18 shows flood hazard map of the study area.

$$FHM = 0.26 \text{ Rainfall} + 0.23 \text{ Drainage Density} + 0.20 \text{ LULC} + 0.07 \text{ Soil type} + 0.12 \text{ Slope} + 0.12 \text{ Elevation.}$$



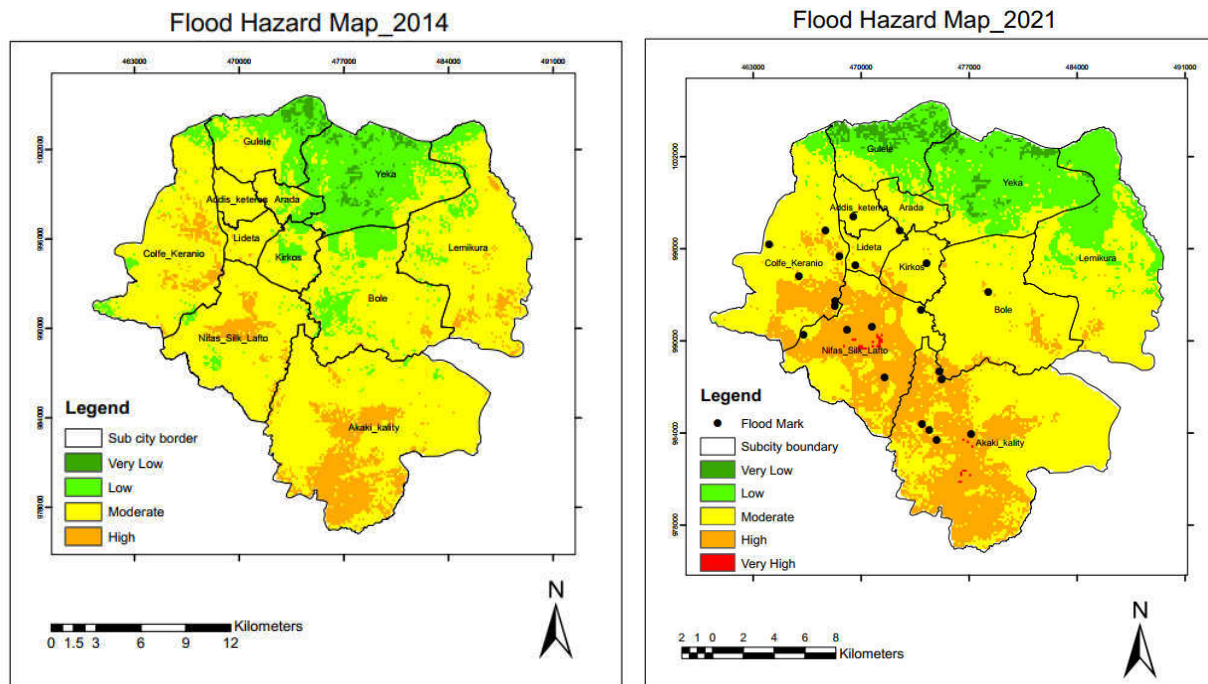


Figure 18. Flood hazard map

## 4.2 Discussion

### 4.2.1 Land use Land Cover change

when the study began in the base year 1992, the pattern of LULC as the percentage of the total area studied was dominated by barren land, covering 28.82% of the total studied area, followed by Agriculture 25.24%, Built up area 25.05%, waterbodies 11.86% and Forest 9.02%.

According to the analysis of LULC changes during 1992–2021, the built-up area increased from 13,013.04ha in 2010 to 34398.05ha in 2021, barren land decreased from 14,973.75ha to 6950.25 ha, agricultural Land decreased from 13114.15 ha to 3993.97 ha, Forest decrease from 4688.16 ha to 1924.90 and a slight change occurred in water body decrease from 6161.07ha to 4683.00 ha during the same period, as shown in Table 15. The results showed that built-up area has led to significant LULC change from 1992 to 2021. Thus, with a 21,385.01ha increase from 1992 to 2021, the built-up area saw the most noticeable changes. As a result, the proportion of built-up area in the total land has increased from 25.05 % to 66.21%. The analysis of the LULC change showed that the contribution to net change in built up area came from agricultural land and barren land.

Table 15. The area of each LULC class in the year 1992, 2002, 2014 and 2021 (in ha and percentage)

Class Name	year	1992		2002		2014		2021	
	Area	ha	%	Ha	%	ha	%	ha	%
Agriculture		13114.15	25.24	9937.09	19.13	8062.12	15.52	3993.97	7.69
Barren land		14973.75	28.82	15146.76	29.16	8594.33	16.54	6950.25	13.38
Built up area		13013.04	25.05	18549.10	35.71	29709.81	57.19	34398.05	66.21
Forest		4688.16	9.02	3891.84	7.49	2561.88	4.93	1924.90	3.71
Water bodies		6161.07	11.86	4425.38	8.52	3022.04	5.82	4683.00	9.01

#### 4.2.1.1 Accuracy assessment of land use land cover change analysis

The accuracy assessment is a comparison of classification with google earth to evaluate how well the classification represents the real world. Overall accuracy assessment, LULC classification levels for the four dates ranged from 70.97% to 77.00%. with Kappa indices of agreement ranging from 0.63 to 0.64. The Overall accuracy assessment and kappa are shown in the Table 17.

Table 16. producer and user accuracy for the year 1992, 2002, 2014 and 2021

LULC type	Producer accuracy	User accuracy	Producer accuracy	User accuracy	Producer accuracy	User accuracy	Producer accuracy	User accuracy
	1992	1992	2002	2002	2014	2014	2021	2021
Forest	100.00%	100.00%	80.00%	80.00%	50.00%	100.00%	37.50%	75.00%
Built up area	77.78%	100.00%	75.00%	71.43%	93.33%	76.36%	96.23%	80.95%
Agriculture	58.33%	87.50%	68.75%	91.67%	73.68%	87.50%	63.64%	87.50%
Waterbodies	50.00%	50.00%	65.75%	64.50%	66.67%	33.33%	75.00%	60.00%
Barren land	100.00%	33.33%	71.43%	78.95%	57.14%	70.59%	50.00%	66.67%

Table 17. Overall accuracy and Kappa for LULC Classification for the year 1992,2002,2014 and 2021

Overall Classification		
Year	Accuracy	Overall, Kappa Statistics
1992	70.97%	0.628
2002	72.58%	0.63
2012	76.00%	0.6457
2022	77.00%	0.6267

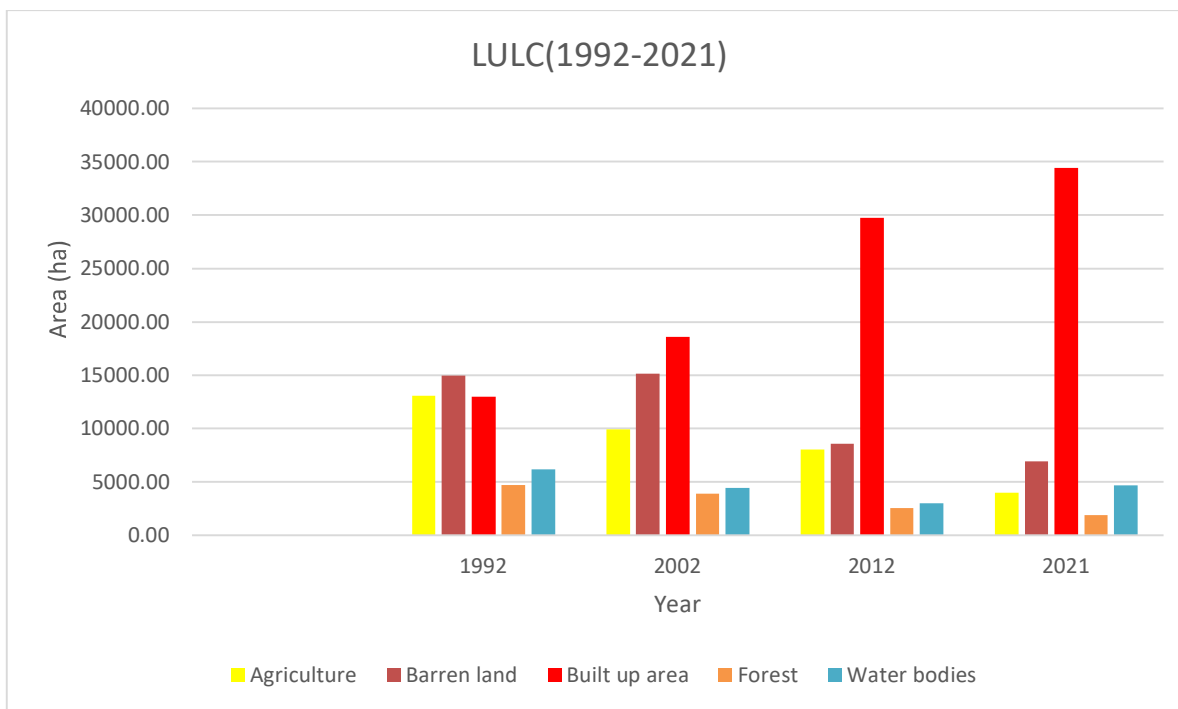


Figure 19. LULC change graph for 1992,2002,2014 and 2021 (in ha)

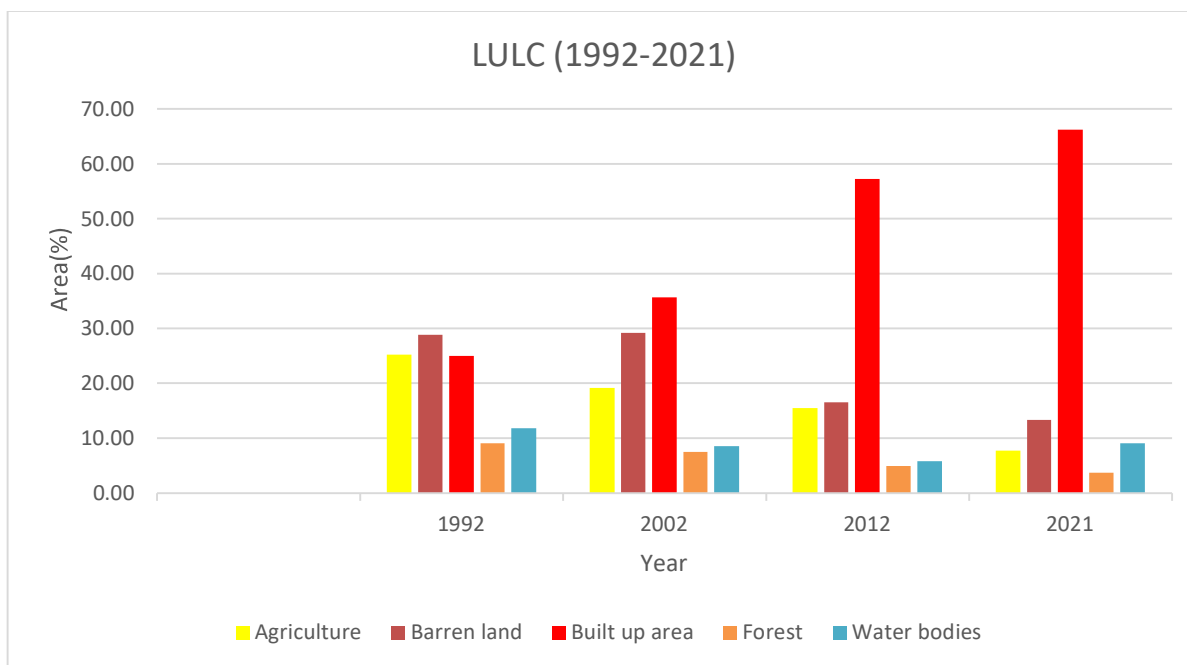


Figure 20.LULC graph for the year 1992,2002,2014 and 2021(in %)

#### 4.2.2 Flood hazard Map

In the base year 1992, In this study flood exposed area high and very high covering 0% and 8.18% respectively from the study area. According to the analysis high exposed area increased in to 9.09 in 2014 and 21.84% in 2021.very high exposed area increased from 0% in to 0.10% in 2021.

Table 18.Flood exposed areas in the year 1992,2002,2014 and 2021(in ha and percentage)

Rate	year	1992		2002		2014		2021	
	Area	ha	%	ha	%	ha	%	ha	%
Very Low		1954	3.83	11656	22.86	8857	17.37	1131	2.23
Low		16890	33.13	1393	2.73	719	1.41	8854	17.44
Moderate		27960	54.85	33754	66.21	36776	72.13	29645	58.39
High		4172	8.18	4176	8.19	4633	9.09	11089	21.84
Very High		0	0.00	0	0.00	0	0.00	52	0.10

## **CHAPTER FIVE**

### **5. Conclusions and Recommendation**

#### **5.1 conclusions**

This study tried to identify LULC change and impact on flooding from the year 1992-2021. This study uses Remote sensing (RS), geographical information system (GIS) and Earth Resource Data Analysis System (ERDAS) techniques and investigated by employing sensitivity analysis method and Analytica Hierarchy process (AHP)method. LULC is one of important factor for flood generating. In this study flood increase from the year1992-2021 in the study area due to LULC change. Most of Agricultural and Barren land area changed to build up area, built up area more flood hazard zone due to less infiltration and have surface runoff.

In order to create a useful food hazard map for the study area, various food-generating factors, including rainfall, slope, elevation, drainage density, land use, and soil, were taken into account. Their corresponding influence was quantified using the AHP method, and it was further validated by using sensitivity analysis and food marks taken from AAFERCPA.

In this study, the factors slope, elevation, and soil had less of an impact on flood generation than rainfall, drainage density, and LULC. The flood hazard map was created, confirmed against flood markers, and shown several flood locations such as very high, high ,moderate, Low, and very Low. Additionally, a flood hazard map indicates potential flood zones. The developed flood hazard map from this research work showed that a high flood hazard has exposed by the flood in the Nifas silk lafto subcity and Akaki kality subcity of the study area.

Most of the study area is changed to Built up area and the built-up area is increase from year to year and parallelly flood increase from year to year due to the fact that LULC change have significant impact for flood generating in the study area. The result of this study is use full for decision maker to drive proper police to manage the land use land cover change

#### **5.2 Recommendation**

As the main objective of the study is to analyze the evaluation of the impact of land use land cover change on floods of Addis Ababa city the following recommendation are forwarded based on the findings. The city administration should develop land use management system, it also provides drainage infrastructure and Integrated flood mitigation measure. To find a solution, the city administration must work with all stakeholders involved in flood control.

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