EVALUATION OF URBAN DRAINAGE SYSTEM AND ITS RESILIENCE; A CASE OF CALALAQA SUBCITY BISHOFTU ETHIOPIA.

SAMSON BENTI FUFA

Thesis Submitted to the department of Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfilment of the Requirement for the Degree of Master's in Urban Planning and Design.

Office of Graduate Studies

Adama Science and Technology University

May, 2024

Adama, Ethiopia

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DECLARATION

I declare here by this research thesis entitled “Evaluation of Urban Drainage System and Its Resilience; A Case of Calalaqa Subcity Bishoftu, Ethiopia.” is my own work and has not been submitted to any university for similar purpose. The reference used in this Thesis are dully recognized by proper citations.

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Name of student	**Signature**	**Date**

RECOMMENDATION OF ADVISORS

I, the major advisor of this thesis, here by certify that I have read the revised version of the thesis entitled “Evaluation of Urban Drainage System and Its Resilience; A Case of Calalaqa Sub city Bishoftu, Ethiopia.” prepared under my guidance by Samson Benti. Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures.

Dr. Yared Girma (PhD) ____________________ ________________

Major Advisor/Supervisor Signature Date

APPROVAL SHEET

I/we, here by certify that the recommendation and suggestion given by the proposal review committee are appropriately incorporated into final thesis proposal entitled "Evaluation of Urban Drainage System and Its Resilience; A Case of Calalaqa Sub City Bishoftu, Ethiopia." by Samson Benti.

Dr. Yared Girma (PhD).	______________	______________
Major Advisor/Supervisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Samson Benti have read and evaluated the thesis entitled "Evaluation of Urban Drainage System and Its Resilience; A Case of Calalaqa Subcity Bishoftu, Ethiopia." and examined the candidate during open Défense. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Urban Planning and Design.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
CSA	Central Statistics Agency
DEM	Digital Elevation Model
FGD	Focus Group Discussion
GIS	Geographic Information System
MCDA	Multi-criteria decision analysis
NDVI	Normalized Difference Vegetation Index
NDMI	Normalized Difference Moisture Index
NDWI	Normalized Difference Water Index
SPSS	Statistical Package for the Social Sciences
USGS	United States of Geological Survey

ABSTRACT

Urban flood resilience is defined as the ability of a city and its constituent systems. The improvement of flood resilience has become an important means for cities to resist flood risks. The study aims to evaluate urban drainage system and its resilience using multi source data in Calalaqa Sub city. Recently, city drainage system along road is facing broad water logging during the rainy season as result of this serious problem of drainage systems. To address the problem specifically study, focus on Investigate and map the flood risk in the Study area. Designate the measures taken by the community and the government in mitigating flooding hazards in the area. The research was carried out using with mixed approaches (quantitative and qualitative) applying Multi-criteria and weighted overlay based on k-means clustering. Data were collected using Key Informant interview and household survey from flood risk areas of the city. From inspection of LULC it is noticed that majority of the study area has the Farm land and urban Built-up land cover. A vegetation or forest cover, slows down and reduces the amount of runoff while urban land cover which is characterized by paved and impermeable surfaces absorbs no water and increase runoff and therefore increases the probability of flooding. The findings revealed that the level of flood risk areas lacked basic infrastructures and had a greater level of perception as compared with low flood risk area. The result of the assessment also disclosed that heavy rain, absence of protective or retaining construction and its maintenance, and poor urban drainage structure were the main perceived causes while housing damage and destruction of household equipment, loss of infrastructure and health problems were effects of flooding in the City. The preparedness and response measures to protect and minimize the flooding hazard found were householders' evacuation from their houses, filling sand in bags and placing around the edges of the premise as well as making a retaining wall-like structure with a hollow block despite it was not strong. In flood protection measures and Early Warning System, the support given from government and non-governmental organizations was inadequate. Thus, the government, community-based organizations and residents should take sustainable strategies for short- and long-term adaptation and mitigation measures.

Key words: urban drainage system, flooding hazards, resilience, Geospatial Technology

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Urban drainage refers to the system that manages the disposal of excess water in a city, including rainwater, domestic wastewater, and industrial wastewater (Guptha et al., 2021a) It is designed to prevent flooding in urban areas and is integrated with sanitation, garbage, city flood control, and the surrounding environment. Urban drainage systems can include various components such as water regulation and storage tanks, ditches, overflow wells, rain grates, and sewer pipelines. These systems aim to effectively drain water, prevent waterlogging, and utilize urban greening to purify rainwater. They also incorporate features like sealing mechanisms, damping holes, and impurity removal mechanisms to improve airtightness, reduce impact, and prevent water accumulation. Municipal drainage systems may also include settling tanks, intercepting nets, and gravel filtering net frames to facilitate silt removal. Overall, urban drainage systems play a crucial role in managing excess water and preventing flooding in urban areas. A large number of flood events around the world lead to thousands of deaths and tremendous losses of social economy. Recently, a study of 616 cities around the world indicated that floods endanger more cities than any other natural hazard, followed by earthquakes and storms (Lukas et al., 2014).

Over the past few decades, urbanization has accelerated in countries around the world. At the same time, climate change, mainly characterized by global warming, has exacerbated the occurrence of extreme weather events (Hansana et al., 2023a) The report of United Nations Office for the Coordination of Humanitarian Affairs 2019 showed that Ethiopia was encountering flooding in numerous parts the country. The figure shows that a sum of 202,202 individuals have been displaced across the nation, the dominant part (127,524 individuals) in Somali region. More than 17,000 family units were displaced in Shabelle zone of the Somali region (Reta et al., 2020).

Considering the changes in precipitation patterns and the damage they have caused in recent years traditional safety concepts and disaster prevention measures are no longer sufficient for most cities in Ethiopia current and future urban development. Therefore, in order to reduce the damage caused by floods and achieve sustainable urban development, it is important to strengthen the flood control capacity of urban communities (Seyam et al., 2023).

Urban flood resilience is defined as the ability of a city and its constituent systems (society, economy, environment, infrastructure, etc.) to resist, cope with, recover from and adapt to urban flood disasters caused by rainstorms or heavy precipitation. Flood resilience is mainly based on the establishment of an index system based on the theoretical framework for evaluation.

As an aftereffect, rapid urbanization around the urban industries in the city causes the land cover modifications, mainly converting vegetative surfaces and barren lands into impervious pavements and infrastructure (Bouhennache et al., (2019) sited in (Guptha et al., 2021a) This would have direct implications on the hydrology of the system, and consequently, a high volume of storm water runoff generation challenges the functioning of the existing drainage System of the urban area (Guptha et al., 2021a). In most situations, these drainage systems are unable to cope with the increased urban runoff, and thus, the occurrence of urban flooding has been frequently witnessed across many cities in the world.

Therefore, effectively managing the urban stormwater has become extensively challenging in the recent past due to urban densification mainly altering the runoff characteristics, such as volume, peak flow, time to peak, and time of concentration (Francisco et al., 2023a). Currently, there is a rapid increase of impervious (developed and paved) areas which aggravates flash flooding, poor solid waste management practices, and less integration of utilities with drainage systems in study area.

As global significance of flood events Floods can be destructive to humans and the natural environment, but they also help to drive biodiversity and are essential to the functioning of many ecosystems. Flood risk increases as people seek the benefits of living near water and encroach on flood vulnerable areas. Flood risk is one of the most significant environment and societal challenges.

Furthermore, weak infrastructure, insufficient policy implementation and lack of flood response plan, land use changes have considerable contributions on flood frequency and magnitude (Mamo et al., 2019). In many rivers of Ethiopia, flood can cause a range of impacts and risks such as pollution of drinking water, death and injury, distraction of houses and livelihood, displacement and distraction of the community and wildlife. Nowadays

Many parts of Ethiopia are affected by flash, urban, and riverine floods frequently during season triggered by heavy rainfall events.

In Global Challenge of Drainage systems are vital infrastructures and utilities of roadways that enable the pavement of the road to resist storm water and other environmental stresses (Jemberie et al., 2023). Due to the combined effects of climate change and poor or inadequate drainage facilities, observing frequent surface floods during rainy seasons has become a common tragedy in most rapidly sprawling urban environments. Urban areas are the living places of more than half of the world's population and consume three-fourths of the resources; however, they occupy only 2% of the land surface. By the middle of the 21st century, it is projected that the population of the world living in urban areas will rise to 70%. As a result, the number of megacities (having a population greater than 10 million) will increase to over 20, of which 80% are in developing nations (Wihlborg, 2019) sited in (Francisco et al., 2023b) which makes sustainable urban drainage a critical and vital issue.
The drainage systems, which have evolved through history, represent compromises between ecological needs, human wellbeing, technical abilities and availability of resources. Only in recent years has the depletion and degradation of urban water resources led to that: advocacy of a sustainable urban water system, characterised by lower water consumption, preservation of natural drainage, reduced generation of wastewater through water reuse and recycling, advanced water pollution control, and preservation and/or enhancement of the receiving water ecosystem.

1.2. Problem the statement

Uneven growth of urban development has compromised the long-term sustainability and the performance of the urban drainage systems and has led to extremely unsatisfactory/ unhealthy conditions (Guptha et al., 2021a). Besides poor planning, designing, and constructing urban drainage systems, several other difficulties, such as precipitation extremes and anthropogenic climate change, also impose considerable uncertainty. Therefore, the proper functioning of stormwater drainage system is crucial to manage the unprecedented urban flooding.

The lack of our understanding on the impacts of climate change and urbanization is a strong barrier in establishing an effective integrated urban drainage implementation plan. Other drivers affecting the drainage systems and their efficiencies must be recognized by monitoring and regular inspection, where the information is lacking in the initial stages of integrated planning. This would provide the design engineers with updated input data for the planning and design of drainage systems. Rather than investigating uncertain future factors, revising the design process through integrated design and planning could reveal the deficiency of the existing systems and also help engineers and decision makers to establish a place-based design framework (guru, et al. 2021).

In the study area specifically, area surrounding lake calalaqa of drainage systems problem such as overflowing on the along road surface, residential surrounding lake, small urban farming eroding the main road at the overflowing area, and taking water in open ditches or on the surface at rainfall season. This problem may due to not adequate drainage ditches, the network of the canal's infrastructure is not well connected, an incremental of rainfall, the increase of pavement in overall the catchments, or an increase in urbanization and in most flat areas the water stagnation is the other critical problem during the rainy season. The study conducted on similar situation focus on theorises part, but this study mainly evaluating the existing (current) situation using additional criteria will be applied.

To address these problems the researcher initiated to evaluate the existing drainage system in study area. As well as to indicate a way management has to reduce the amount of runoff entering into the drainage system. Recently, Bishoftu town drainage system along road is facing broad water logging during the rainy season as result of this serious problem of drainage systems.

1.3. Objective of the study

1.3.1. General Objectives

The general objectives of the study is to evaluate the urban drainage system in Calalqa Sub City, Ethiopia, and assess its resilience to effectively manage stormwater and prevent flooding.

1.3.2. Specific objective

The Specific objective of the research are designed as follows;

1. To Investigate and map the flood risk, and flood vulnerability hotspot sites in the Study area.
2. To Analyse the spatial distribution and capacity of the drainage network
3. To Designate the measures taken by the community and the government in mitigating flooding hazards in the area.

1.4. Research questions

The following research questions are identified based on the objectives.

1. Which area of the drainage line is affected by flood hazards and what percentage of the area is highly affected?
2. How does the spatial distribution of the drainage network influence its capacity to manage stormwater runoff?
3. What the measures taken by the community, the government and NGOs in mitigating flooding hazards in the area?

1.5. Significance of the study

Urban drainage infrastructures are facing critical challenges due to a lack of integrated asset management, periodic maintenance, improper design, and construction methodologies. Numerous researches evidenced that flooding has socio-economic, environmental and psychological effects on the household livelihoods. In order to minimize and avoid the problem, there should be a research that can identify perception and response to flooding due to improper drainage system in the study area.

Hence, this research can be helpful from the following perspectives. First, it can provide valuable information about household's perception and response to flooding in Bishoftu City and may provide some ways in which the community in flood risk prone areas protect themselves from the flood. Secondly, findings of the research may be used by the concerned bodies in the study area (government offices, NGOs, community) and it can also contribute to the literature on studies related to flooding hazard and this may open the gate for further studies. As such, it will also encourage other researchers to conduct a study in the sector with a wider scale and greater depth. As an outcome of this study, the concerned governmental organizations and NGOs working in the area will make objectives and well-informed decisions.

1.6. Scope and Limitation of the study

Geographical scope of this study was bounded to Calalaqa sub city. The study focuses on the evaluation of urban drainage system and structural resilience approach using multi source data in Calalaqa sub city. To make the study more manageable and be completed within the specified time and available resources, the study was targeted some part of urban area in Calalaqa sub city. The impact of flooding on socio economy and socio-cultural of the community situation should be examined. The study was also based on quantitative data was collected from household heads about perception of and response to flooding hazard residing along flood prone areas. Besides, qualitative data was collected from Key Informants and city municipality as well as concerned regional Environmental authorities in the year 2024. On the limitation of the researcher faced major constraints; these are lack of interest on the respondents' side, political instability and time constraints. When the researcher conducted the household survey, the target groups were not willing to fill questionnaires, by presuming that the result of this research does not have impact for the area.

1.7. Operational Definition

Flood: is an overflow of water that submerges normally dry ground. (Pidwirny, M., (2006).

Resilience: resilience is defined here considering the behaviour of an urban drainage risk management (UDRM) system in terms of its response and recovery.

Flood Resilience is a term that has become more commonly used, and generally means that damages are minimized during times of flooding resulting in less risk to people and infrastructure and ensuring that there is ample room for flooding and river adjustment to occur where the opportunity may exist.

Drainage system: The flow of water through well-defined channels is known as 'drainage' and the network of such channels is called a 'drainage system'. The drainage pattern of an area is the outcome of the geological time period, nature and structure of rocks, topography, slope, amount of water flowing and the periodicity of the flow. **(**Cristiano (2022)

Hazard: Any source of possible damage, harm, or adverse effects on something or someone is considered a hazard.

Response: Flood risk response is an attempt to reduce the impact of a single flood disaster. Flood response can take a variety of forms. This is shown in the many adaptation methods implemented in the aftermath of a flood, such as relief and rehabilitation, insurance, warning systems, technological aids, and land use management.

Risk: The likelihood of flooding having harmful implications for the human population.

Risk perception: Risk perception is the view of risk held by a person or house hold/group and reflects cultural and personal values, as well as experience. (world Bank,2022)

1.8. Organization of the study

This study was organized into five chapters. The first chapter was the introductory part that includes the statement of the problem, objective of the study, scope of the study, research questions, and scope of the study and methodology used, second chapter review deals with literature review and the literatures that related to study with evaluation of urban drainage system and its resilience. Chapter three describes about the methodology of the study, Chapter four deals with analysis of the findings of the study. Fifth chapter conclusion and recommendation with the possible mitigation measures and the last reference and appendix were included in this study.

CHAPTER TWO

2. REVIEW OF RELATED LITERATURE

2.1. Theoretical Review of Urban Drainage system and concepts

Drainage is an integral part of different areas or environment (e.g. urban, rural, forest, and agricultural etc.) to remove unwanted water volume (Ar Rashid, 2023). It can be defined as the natural or artificial way used to remove unwanted or excess water from any surface or sub-surface area. Here, urban drainage includes the removal of unexpected water from urban areas (i.e., domestic and industrial wastewater) along with sewerage, grey-water, heavy rainfall, and stormwater.

Over more than a century, urban drainage systems have been constructed in cities across the world in order to prevent the nuisance from flooding by quickly removing the runoff from urban areas. Combined stormwater and wastewater drainage systems were also provided with the similar objective in some parts of the world. The history of drainage system construction dates back to the early third millennium BC during the Indus civilization (Yazdanfar & Sharma, 2015).

In the late 18th century, a progressive attention was provided to wet-weather flow management, intending to transfer the increased runoff further away from urban area, which required larger stormwater collection systems (interceptors) with respect to the growing population. It resulted in higher investment cost for overall urban drainage systems. As the combined systems transported sewage from the urban area to receiving water bodies, anthropogenic pollutants in watercourses were recognized by the middle to late 19th century. This problem was further aggravated by rapid urbanization. Consequently, treatment practices were initiated as the next major step in drainage system design. The problem also initiated a debate on the adoption of either combined or separate sewer systems.

By the late 20th century, problems associated with drainage systems' failure, such as flooding, downstream erosion, deteriorating water quality, and environmental issues, were addressed by sustainable practices entailing detention/retention basin, bio-filtration trenches, porous pavement, sand filters, and water quality inlets (Yazdanfar & Sharma, 2015). In particular these practices intended to address the climate change effects of increase in runoff rate and volume on drainage systems. However, these approaches impose additional capital and maintenance costs to drainage systems.

The practice of urban drainage system has been traced back to some hundred years ago. The efficient conveyance of storm water from urbanized areas was motivated primarily by reasons of convenience and the reduction of flood damage potential. Such practices which were aimed to improve the quality of urban life have resulted in other problems, such as artificially induced flooding, increased erosion and environmental degradation originating from the pollution of receiving waters. As a result, attention has given to the comprehensive management of urban drainage systems including the implementation of storage and treatment facilities (Assimamaw Assefa, 2021).

2.1.1. History of urban drainage design approaches

An urban drainage system is generally defined as a runoff collection and transportation system, which is responsible for quickly removing stormwater runoff only from urban areas to prevent any flooding. Such systems are known as separate drainage systems and are widely used in Australia and North America. However, combined sewer systems, which transport urban runoff as well as municipal wastewater, are still working in some part of the world (Europe, Asia, and Africa) (Yazdanfar & Sharma, 2015).

Conventional sewerage and wastewater treatment systems evolved over many centuries in response to changing problems. Originally open channels (sewer system) were used to transport rainfall runoff (stormwater) away as quickly as possible from the city's populated centre and prevent local flooding. As indoor plumbing became popular, the sewer system was used to carry wastewater as well. However, over time, these open channels became contaminated and caused objectionable odour problems. This led to the use of closed sewers (combined sewer systems) discharging to the nearest watercourse.

The evolutionary path leading to the development of conventional urban drainage and wastewater treatment systems has resulted in an approach to the collection, conveyance and treatment of urban stormwater runoff and wastewater flow that involves the routing of as much flow as possible to an “end-of-pipe” facility which may be an outfall or a wastewater treatment facility. Most communities and municipalities are therefore served by a collection of combined or separate sewers subject to varying degrees and levels of wet-weather induced inflows that cause the discharge of untreated stormwater and wastewater overflows into the receiving environment.

Sewers have traditionally therefore been designed on the basis of their peak flow capacity in order to convey as much water away as quickly as possible. This has resulted in the tendency to build bigger and bigger interceptor sewers and tunnels in response to the increasing urbanization process and to replace the aging infrastructure. The conveyance of larger and larger flows to outfalls and wastewater treatment plants presents flow handling challenges with the associated risks of washout of sensitive treatment process stages and often necessitates costly upgrades in infrastructure to cope with the increased flow regimes.

2.1.2. Impact of Urbanization on Rainfall- Runoff Processes

Urbanization is an important index to reflect the development level of a country, but it is enhancing the interaction between human society and the environment. The unbalance of the water conservancy facilities transformation and the rapid urban development resulted in considerable urban water problems. Urbanization increases the risk of flooding due to increased peak discharge and volume, and decreased time to peak that restricted the development of cities. In highly urbanized areas, over half of rainfall becomes surface runoff, and deep infiltration is only a small fraction of natural situation (Assimamaw Assefa, 2021).

Rainfall-runoff process is known to be related to complex factors in urban, such as land use/cover, river network morphology, construction of drainage system and water transfer. The complexity of underlying surface, the uncertainty of anthropogenic disturbance, and lack of high-quality datasets for calibration and validation may limit research for the rainfall-runoff processes in an urban catchment (Guan Mingfu et al., 2015) sited in (Assimamaw Assefa, 2021)

2.2. Flood Resilience

The term resilience is defined as define resilience as: ‘bouncing back from a terrible event’ or ‘having the strength to cope’ or ‘being determined to See things through the end (Tilahun & Worku, 2020). Form these definitions we can realize that people being mentally strong, sufficiently strong to maintain a sense of wellbeing whilst facing challenges. According to the European Commission, 2012 cited in (Zhang et al., 2023) defines resilience as *“the ability of an individual, a household, a community, a country or a region to withstand, to adapt, and to quickly recover from stresses and shocks”*. Hence, it’s significant to achieve the concept resilience in any scenario especially, areas that are prone to different kinds of hazards.

Floods cause more damage worldwide to human life and property than any other type of natural disaster. This trend shows no sign of reduction. Many of the efforts to address flooding so far have been focused on recovery. Though, to reduce flood losses and help communities in both developed and developing countries improving flood resilience, is very crucial that it should be more focused mitigating risks and prepare for floods, rather than simply dealing with the consequences after a flood occurs (Tilahun & Worku, 2018). Hence, relying on traditional flood control measures is recognized as inadequate, since the damage can be catastrophic if flood controls fail. The idea of a flood resilience is the one which can withstand or adapt to a flood event without being harmed in its functionality (Restemeyer, et al., 2015) sited in (Biruk Tilahun, 2018).

Resilience strategies can be characterized in general as strategies that allow floods, but aim at minimizing flood impacts, maximizing recovery rates, for all possible flooding types. They aim at increasing the capability of a system to recover from flood impacts. The measures used in a resilience strategy may change the flood probabilities or the impacts for specific locations within the system. They comprise both structural and non-structural measures. The flood probability can be changed by, for example, decreasing the protection of natural areas, or increasing that of cities, while flood impacts may be reduced by e.g. raising flood risk awareness and changing land use. Both types of measures may increase the resilience of the system as a whole since expected damages are lowered, recovery is enhanced and the reaction to flood waves may become more gradual.

Flood resilience can be enhanced through different ways that are stated below:

- Through better assessments of flood hazards and communicating the risk to residents.
- Taking measures to lessen the severity of floods and mitigate their impact, including first-aid and health training, community planning, and setting up emergency shelters.
- Gaining a better understanding of how decisions are made in the face of risks and uncertainty to make the most effective solutions easier to find.
- Improving warning systems and helping communities adopt emergency protocols.
- Supporting efforts to rebuild ‘better’ to safer standards after floods.
- Ensuring people have opportunities to secure an income during floods.

2.2.1. Flood Resilience in the Context of Risk Management

Flood Resilience is a term that has become more commonly used, and generally means that damages are minimized during times of flooding resulting in less risk to people and infrastructure and ensuring that there is ample room for flooding and river adjustment to occur where the opportunity may exist. It also means that flood recovery may be less expensive and may get people back on their feet more quickly than in past flood events, and that the water resource is not negatively affected and is able to recover on its own. It is a way of helping people and communities live with and plan for flooding.

According to (Biruk Tilahun, 2018) ‘Floods cannot be prevented but planning the emergency measures through flood management can often reduce their disastrous consequences’. He emphasized that only a comprehensive approach which covers all aspects of disaster management cycle, including an appropriate balance of prevention, mitigation, preparedness, response, recovery and disaster-related development, can be effective.

Flood risk management implies two main types of measures that are distinguished by their aim: structural and non-structural measures. Traditionally the focus has been on reducing the probability of flooding through extensive structural Défense systems or pure engineering such as those found in the Rotterdam in the Netherlands. Increasingly, there is the recognition that non-structural actions often aimed at reducing the vulnerability of people and communities, such as flood warning, effective flood emergency response, or resilience measures offer a vital contribution to risk management.

2.3. Flood hazard and risk mapping

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 facilitate the identification of areas at risk of flooding and also helps prioritise mitigation and response efforts (Renu Bali, 2021). Flood hazard maps are designed to increase awareness of the likelihood of flooding among the public, local authorities and other organisations. They also encourage people living and working in flood-prone areas to find out more about the local flood risk and to take appropriate action.

Hazard maps provide important information to help people understand the risks of natural hazards and to help mitigate disasters. Hazard maps indicate the extent of expected risk areas, and can be combined with disaster management information such as evacuation sites, evacuation routes, and so. Development and provision of flood hazard and flood risk maps has a vital role as per prevailing hazards and risks (Prinos, 2008) sited in (Biruk Tilahun, 2018) Such maps generated will immensely help understanding flood risk for the following listed below:

- Awareness Creation: - Flood maps can increase public awareness of the areas at risk from flooding. To be effective, the public must believe the maps to be accurate, have a clear understanding of their content and have ready access to them (van Berchum et al., 2020).

- Spatial planning**: -** Flood maps can differentiate the spatial distribution of risk within the floodplain to support spatial planning decisions. To be effective, the evidence presents in the flood maps (present day and future) must go hand-in-hand with spatial planning processes.
- Asset Management: **-** Flood maps help in prioritizing, justifying and targeting investments, in order to manage and reduce risk to people, property and the environment (Prinos, 2008).
- Emergency and Evacuation Planning: - (van Berchum et al., 2020) stated that flood hazard and risk mapping has a great role in emergency and evacuation planning with regards to:

A. Encouraging professional emergency responders (police, army, fire and ambulance) to focus on vulnerable sites and assets in the floodplain, and determine whether specific mitigation actions are needed to reduce the potential impacts should a flood occur.

2.3.1. Causes and Consequences of Flooding

Floods are among the most devastating natural disasters that occur worldwide, affecting millions of people and causing significant damage to both human settlements and the environment. As our planet experiences the impacts of climate change and human activities continue to alter landscapes, understanding the main causes and effects of floods becomes increasingly crucial. According to (Ayele, 2018), floods are caused by many factors such as heavy rainfall, highly accelerated snowmelt, severe winds over water, unusual high tide, tsunamis, or failure of dams, levees, retention ponds, or other structures that retained the water. In other way, flooding can be exacerbated by increased amounts of impervious surface or hard ground cover that not allow the water to pass thorough as well as by other natural hazards such as wildfires, which reduce the supply or the amount of vegetation cover that can absorb rainfall.

(Teshome, 2020) indicated that floods can occur due to meteorological partly or other causes, which can exacerbate the occurrence of flooding. Meteorological causes include snowmelt, rain, and combination of rain and ice melt. Coastal storm surges and estuarine interactions between stream flow and tidal conditions entail the partly meteorological causes. The remaining causes of floods can be attributed to other natural hazards such as earthquakes, landslides, Tsunamis and hurricanes or human caused (technological) hazards such as dam breaks, fail levees, dykes, weirs and terraces. The cause of flooding can be described according to the water source, geography of receiving area, cause and the speed of onset.

Water source-related floods can originate from the ocean (coastal floods), rivers (fluvial floods), from underground (groundwater floods) and from rain (pluvial floods). These major flood types will each be described in terms of its geography, cause, and onset speed.

2.3.2. Flood Disaster Management

In the management of flood disasters, flood hazard/risk mapping is one of the vital steps undertaken to prepare for and mitigate the effects of a flooding event. Some of the other vital steps may include vulnerability analysis, climate forecasting, flood plain management and enforcement of standards and codes.

2.4. Flood scenario in Ethiopia

In recent years, many urban areas in Ethiopia have experienced frequent flood events as a result of climate change and urban sprawl. Unplanned and unsustainable poor urban storm water management strategies will aggravate the impact and frequency of flood occurrence. In Ethiopia flooding usually occurs within the three months of the rainy season and limited to areas of lower and flat topographic setting. It is usually the intense rainfall in the high lands that cause flooding at its downstream and disaster to settlements close to any stretch of river courses (Lukas et al., 2014).

Moreover, flood hazard is common to the floodplains which are normally located along the rivers at the downstream parts of the river courses. The Awash River Basin is one of the five main basins which has encountered wide floodplains along its courses. At its middle and lower catchments there are known flood events once every year during the rainy season of summer. In the lower catchments the hazardous flood to agriculture and settlement is caused by the over flow of river Mille and Logiya which are main tributaries of the Awash River. In its middle catchment, Kessem and Kebena are other tributaries of Awash River that cause main flooding.

2.5. Empirical Literature

Study conducted by (Guptha et al., 2021b) presents a comprehensive evaluation of the UDS of Gurugram City, India. While the limited availability of sub-hourly precipitation and finer resolution geospatial data pose major challenges in the detailed analyses through Storm Water Management Model, it was circumvented by utilizing the high-resolution remotely sensed datasets. As the results Functional failure scenarios (i.e., the combinations of climate change and urbanization) were simulated to assess the impacts on the resilience of the UDS.

From Scholars studied about failarity of urban drainage system (Najib, 2016) stated that functional failures are caused by external factors, mainly due to high-intensity storm events or highly impermeable surfaces. The occurrence of rainfall extremes can be attributed to both natural and anthropogenic climate change. Similarly, impervious surface covers as a consequence of urbanization inflates the surface runoff volume.

(Zhang et al., 2023) conduct research on constructs an assessment model of urban flood resilience using different aspects: infrastructure, environment, society and economy. Then they quantify infrastructure and environmental vulnerability based on GIS. the Author state that the results show that different factors have different effects on flood resilience, and cities with low infrastructure and environmental vulnerability and high socioeconomic recoverability are more resilient in the face of floods.

(Ziwei et al., 2023) also study on GIS-based risk assessment of flood disaster in the Lijiang River Basin. The scientific reference for the establishment of rainstorm and flood disaster prevention system in Guilin region and improve the risk assessment of rainstorm and flood disasters. To realize the goal, a flood risk evaluation model is established by weight analysis methods including the entropy weight method and the analytic hierarchy process from 3 aspects, i.e., risk of disaster causing factors, sensitivity of disaster-pregnant environment and vulnerability of disaster bearing body. Meanwhile, they used ArcGIS for analysis and calculation to complete the risk assessment of flood disaster The results indicate that: the hazard level of flood disaster causing factors in Lijiang River Basin shows a decreasing distribution pattern from north to south, and high-risk areas cover 3108.47 km2, accounting for 21.29%; the stability grade of disaster-pregnant environment shows a decreasing trend from the surrounding mountains to the plains, and the low stability and lower-stability areas are mostly found in the low-lying areas.

(Ayele, 2018) conducted study the urban households' vulnerability to flooding hazards in Addis Ababa. She focuses on mainly meant for analysing the status and dynamics of land use land cover (LU/LC) as a cause for flooding hazards, and the level of inundation. According to author the results show that The LULC dynamics in the area was found to be very high, leaving the area vulnerable to flooding. The result of the purposely selected informants and discussants reveal that flooding in Ginfile catchment and its adverse impacts are very high due to high urbanization which changed the vegetation cover in to buildings and industries as most of the time manufacturing industries built along the riverside. Finally, they state that in addition to flooding hazards, the river is becoming source of pollution in the area as various types of wastes are disposed in it. This has become a serious health problem for the population along the riverside and still not given proper attention by the city administration.

(Tefera, 2020) conduct study on “Assessment and Modelling of Urban Drainage System Performance in mojo town”. Drainage problem in mojo town the worst issue of over flooding on the surface runoff at high rainfall season. This difficulty occurred due to inadequate drainage network infrastructure and the increase in the urban pavement on most urban sub-catchments. In their study they identify the critical condition and related problem with a drainage system, assess the hydraulic performance of stormwater drainage infrastructures, and to evaluate alternatives for drainage problem mitigation measures.

(Orencio & Fujii, 2013) study A localized disaster-resilience index to assess coastal communities based on an analytic hierarchy process (AHP). Author state that the increased number of natural hazards due to climate variability has resulted in numerous disasters in developing countries. the common approach to mitigate disasters in this area is to enhance the inherent capabilities of local communities to reduce the effects. The composites of the index were determined through a process of prioritizing national-level components of a risk management and vulnerability-reduction system. The results showed that the environmental and natural resource management, sustainable livelihood, social protection, and planning regimes were very important and represented >70% of the overall weights of criteria subjected to comparisons. These criteria and their elements represented the local-level outcome indicators of the composite index for a disaster-resilient coastal community, which was measured using a weighted linear average (WLC) approach to both outcome and process indicators.

2.6. Conceptual framework

2.6.1. Remote Sensing and GIS approach

GIS and remote sensing technologies contribute to hazard mapping and prediction. By analysing historical data, topography, and other relevant factors, GIS can help identify areas at high risk of natural disasters, such as flood-prone zones or landslide-prone areas.

(Erena et al., 2018) has generated efficient and cost-effective methodology for preparing flood hazard maps in Ghana, particularly those regions where floods pose a recurrent danger. The level 1b ASTER imagery, topographic map covering the study area at a scale of 1:50000, the contours generated DEM, land cover and demographic data has been used to create a district level map indicating flood hazard index for district scale using an additive model which was adapted for their study.

(Forkuo, 2011), has illustrated the case study of the Susan River, Ghana. they employed the land cover data obtained from classified ASTER image, the contour generated DEM, the geometric data extracted from the DEM, topographic map and field measurements collections. (Asongu et al., 2016) perform the basic flood risk assessment by combining aerial photo interpretation, the use of data questionnaires in a community-based field data collection, and subsequent analysis using Geographical Information Systems (GIS) in study area of San Sebastian based on traditional hydrological modelling.

2.6.2. Vulnerability Analysis

Vulnerability assessment, one of the most important phases of penetration testing, occurs when your team maps the profile of the environment to publicly known or, in some cases, unknown vulnerabilities. The population and structures within areas delineated as flood-prone are looked at during a vulnerability analysis. During the vulnerability analysis, the potential costs of flooding are evaluated as pertaining to damage of critical infrastructure such as utilities, bridges roads, buildings and crops. Because vulnerability analysis detects the population at utmost risk, it can also be used to determine the emergency responses that may be essential such as temporary shelters and evacuation parameters According to United Nations (2012) sited in (Alam et al., 2023).

Remote sensing and Geographic Information System (GIS) techniques have been successfully made use of in flood vulnerability assessment (Hansana et al., 2023b). Also, a variety of approaches such as GIS overlay analysis (Periyasamy et al. 2018), Multi-criteria decision analysis (El Moussaoui et al. 2017), fuzzy approach (Lee et al. 2015), Random forest approach (Lee et al. 2017) etc. have been used in vulnerability related studies. Geographic Information System (GIS) based Multi-criteria decision analysis (MCDA) is a collection of methods for evaluating and combining geographic data and user preferences to aid in decision making (Malczewski, 2006). Because of its flexible nature for analysing multiple and conflicting criteria, MCDA approach can be widely used to spatially represent flood vulnerability related studies (Giupponi et al. 2014, De Brito and Evers 2016; Feizizadeh and Kienberger 2017). Moreover, interests from different stakeholders are incorporated in MCDA in the form of criteria weights, thereby providing a solution for a multi-dimensional problem such as flood vulnerability which could be viewed under economic, physical, social, environmental perspectives. Analytical Hierarchy Process

(AHP) is a widely used tool for multi-criteria decision making, providing an effective means to address complex problems in decision making (Vijith & Dodge-Wan, 2019).

2.7. Research Gap

In addition to the above methods, recent studies have begun to consider the combination of vulnerability and resilience to consider flood resilience, which can better consider the interaction and connection between various factors, based on the quantitative model of the correlation between vulnerability and resilience, an urban flood resilience evaluation model from pre-disaster exposure, disaster sensitivity and adaptability, and post-disaster recovery ability to evaluate the resilience of flood disasters.

However, the flood resilience evaluation index system established considering vulnerability and resilience is limited by the influence of the database, and only limited indicators can be considered. The data source is also single statistical data, and the accuracy of the data also determines the usefulness of the analysis results. Most studies only ranked the flood resilience of cities in the study area separately, unable to identify clusters of cities with similar characteristics, and cities with similar characteristics often have the same problems. Therefore, further research is required.

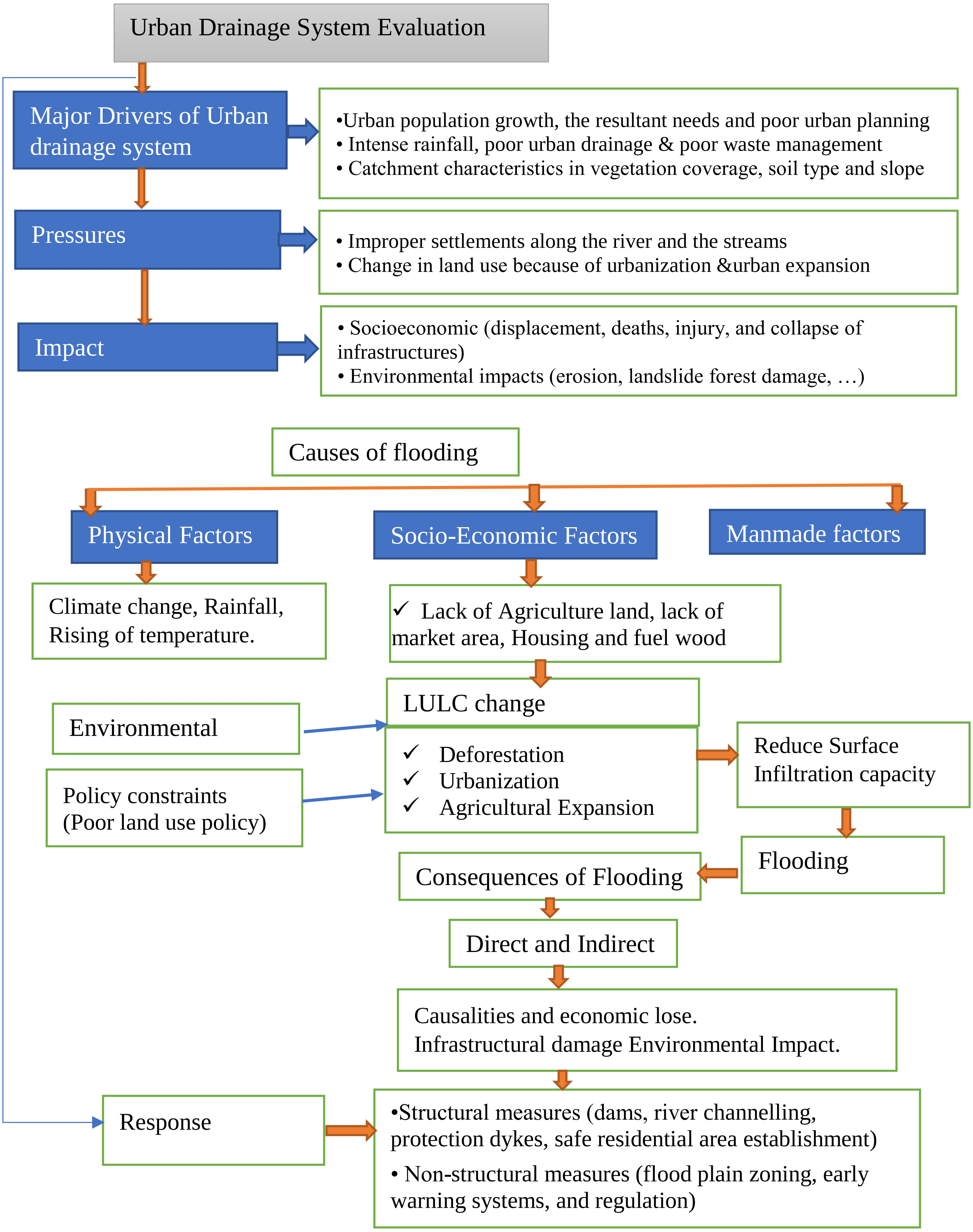

Figure 2.1. Conceptual framework of the study

Sources (Assimamaw Assefa, 2021) and modified by Author 2024.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of study area

The Study area is located in Oromia National Regional State, East Shewa Zone at a distance of 47 km southeast of Addis Ababa and is astronomical location is 8º 43'- 8º 46' North Latitude & 38º 56'- 39º 01' East Longitude on an average elevation of 1,920 m. The town was founded in 1917 GC. Bishoftu is one of the reform City in Oromia regions and has a three (3) Sub city and Eleven (11) wereda under it.

3.1.1. Location Description (Geographical)

The city is located between 8° 45′ 00'' - 8° 47' 00'' North latitudes and 38° 56'00''-39°00'00'' East longitudes and has an altitude that ranges from 1746m to 1995m. It is situated at a distance of 47 km South East of Addis Ababa, and 52 Km from Adama. In the North the city is bordered with Yerer Silassie, in the south with Wedo and Keta Jara, in East with Kaliti and in the West with Dire town and Peasant Association. Formerly known by the name Debre Ziet Bishoftu city is found in east shoa zonal administration. Location map of Bishoftu city in Oromia, Ethiopia Figure 3.1.

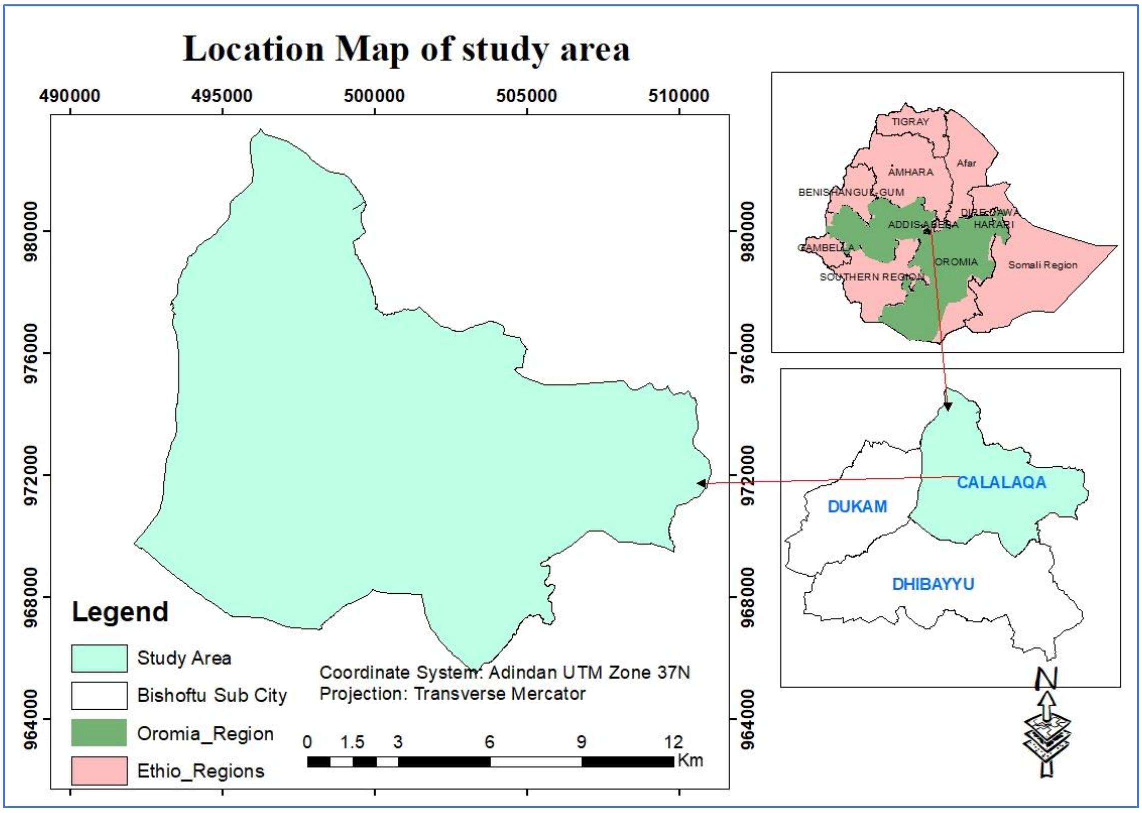

Figure:3.1. Location map of Study area Calalaqa Sub City Bishoftu Ethiopia.

3.1.2. Urban Drainage system

Drainage Surface flow direction is determined by topographic features, nature of soil, vegetation cover and human impacts. Based on the topography of the city, Seasonal streams flow from northern direction to the central part of the town (some draining to the lakes) and then flow to southeast direction. On the other hand, Surface run off from southwestern parts of the town flows to southeast direction. At the same time, Surface runoff from northeast direction also flows to southwest until it is blocked by the upland areas Located around and near the Lakes. Thus, appropriate watershed management should be carried out to reduce risks of siltation and hence increase the volume of Lakes by timely supervising the watershed and diversion channels.

3.1.3. Climate Condition

According to the Ethiopian Traditional climatic zone classification, areas which lies on an altitude ranging from 1500 – 2300 meters is considered as Weiyna Dega (Midlands) (Biruk Tilahun, 2018). Bishoftu town's climatic zone can be considered as Weyna Dega agro-climatic zone since the altitude of Bishoftu also lies between 1835 – 2359 meters. On the other hand, the average annual rainfall and temperature data of the town is 860mm and 19.32 ^{0}C respectively. In Bishoftu, the wet season is mostly cloudy, the dry season is partly cloudy, and it is warm year-round. Over the course of the year, the temperature typically varies from 54°F to 80°F and is rarely below 49°F or above 85°F.

3.1.4. Population description

According to the 2013 Population projection of Central Statistics Agency (CSA), Bishoftu city has a total population of 128,408 but as per Ethiopian urban studies of 2015; the population of the city is 140,039 and sources from the city administration show that total population of the city is 200,064 in 2016.

The presented division in districts follows the 2007 census atlas and current official projections. The actual number of districts and district-level towns is higher. Also, several boundaries have changed since them. The total population projected 2022 male 98277 and female 109,106.

3.2. Research Design

A well-planned research design helps ensure that our methods match research aims, that you collect high-quality data, and that you use the right kind of analysis to answer your questions, utilizing credible sources. This allows us to draw valid, trustworthy conclusions. This study focuses on descriptive and exploratory research designs which involving qualitative data so as to describe and examine the findings to come up with conclusions and recommendations for implementation.

The descriptive type was used to describe the existing condition and coverage of Urban drainage facilities and its integration. Whereas, the exploratory type was particularly used to explore the existing condition by making some required physical measurements, and compare with standards and coverage of urban drainage facilities which were not found in the base-map, and will be collected from the Bishoftu city Infrastructure Asset Management Plan.

3.3. Data Type and Sources

The study used both primary and secondary data sources. The secondary data were collected from available reports, documents and published articles, journals, books, magazines, and broachers. Primary data were gathered from different stakeholders such as households affected by floods or subjected to flood, service providers such as City administration, and metrological Agency at different spatial levels. Table 3.1. show the data types and sources.

Table: 3.1. Data sources

Data Description	Types of data/format	Sources
Land use	shapefile	Bishoftu city
Base map & Masterplan	Shape file/scanned	Bishoftu city
Boundary	Shape file	Bishoftu city
Drainage data	Shape file	Bishoftu city
Population data	-	CSA
Satellite image (Landsat8)	Raster/tiff	Google earth & USGS
DEM	Raster/Grid	USGS

Primary data was gathered through interview question guides, questionnaire and check-list, which was used for key informants, household survey and filed observation respectively. The data for the infrastructure and environment which will comes from remote sensing and GIS data, while the data for the socioeconomic index come from statistical data.

3.4. Software and Materials Used

Software like ARCGIS which is used to display geographic data, analysis spatial data, and can use it to create maps. Erdas imagine which a raster-based software package designed specifically to extract information from imagery. ERDAS IMAGINE includes a comprehensive set of tools to create accurate base imagery for inclusion into a GIS and ESRI Geodatabase and spss for Analysing statistical data was used for this study. Detailed software is listed in table 3.2

Table: 3.2. Software used in study

S/N	Software	Version	Purpose of software's
1	ARCGIS	10.8	Map preparation (spatial analysis)
2	ERDAS IMAGINE	V2015	Image processing and correction (Geometric, Radiometric and atmospheric correction)
3	Microsoft Office	2019	For report writing
4	SPSS	v26	For statistical data processing

3.5. Sampling Techniques and sample size determination

The purposive sample is a type of non-probability sampling which means selecting a sample by the judgment of researcher rather than using mathematical probability for selecting a sample. Purposive sampling is one of the sampling techniques designed and used in this study. Since, it is a type of non-probability sampling technique by which the researcher selects her/his samples based on his/her own judgment that enables the researcher to select samples that are familiar with a certain issue raised by the researcher (Kothari, 2004). So that, the researcher will use purposive sampling in order to select samples who have knowledge about the purpose of the study. In purposive sampling researcher targets, a group form of the general population under consideration based on research.

The sample size was determined by using (Simarjeet Kaur, 2017) standard formulae

$n = \frac{N}{1+N(e)^2}$…………………………………………………………..……….. (equation 1)

Where; n= the sample size

e= the level of precision $(0.08)^2$

N= total population of selected targeted area.

Given:

$N = 3540$

$e = 0.08$ (8%)

n = 3540 / (1 + 3540 * 0.08^2)

n = 3540 / (1 + 3540 * 0.0064)

n = 3540 / (1 + 22.656)

$n \approx 318.6$

finally, the nearest whole number, the sample size is 319 households.

Prior to field investigation, different data relevant to the drainage situation will be collected. This includes, Digital Elevation Model (DEM), Satellite Imagery and drainage design repots. Accordingly, major drainage basins and outfalls in the city prone to the flood will be identified based on the main road passing through the city as a base point of discussion while roads and drainages feeding to this road are considered for integration evaluation. The study will use purposive sampling technique as the areas prone to the flooding as well as the effect of poor integration of road and drainage infrastructure are reflected on the main road passing through the city.

3.6. Methods of Data collection

3.6.1. Structured Questionnaire

In this study a structured questionnaire was designed using literature as a basis. The researcher prepared the questionnaire for sample of 318 households of sub city selected. The researcher prepared scaled questions (Likert and rating scales) as well as multiple and open-ended questions which were used to judge the feeling, attitude and perception of the households. The questionnaire consisted of households ‘flood experience, knowledge, information, levels of preparedness and protection measures and confidence in officials and institution to tackle flooding problems in the study area (For details see Appendix).

This were specifically prepared for sampled Households based on selection criteria affected by seasonal urban flooding in specific study area residents. The questionnaire has both closed and open-ended questions. It will be prepared in an understandable manner in order to make the questions as clear as possible for both the interviewer and the interviewees. Thus, to achieve this there will be one pilot survey to identify the gap between the informants and the Questionnaires.

3.6.2. Field Observations:

Since Field observation is a method where people can observe real location and situation, the researcher had a chance to see the actual condition of the flood prone areas particularly the ecological and other effects of flooding hazard in the study area. Pictures were taken, passions of the respondents were high, and the researcher even had an actual flooding encounter in pure residential on road side. It will be carried out within pre-identified area of challenges related to drainage through transect walk in order to cross check the data gathering by interview and to support their validity through eye witnessing. It is very important as it enables the study to relate the actual type of community problems and validated the existing information and better understanding the prevailing situation of target communities.

3.7. Methods of Data Analysis

After all data collected the analysis of spatial and non-spatial (statistical data) will be analyse using GIS techniques and **spss** tools. The study covers existing drainage system and flood sensitivity assessments restricted to the study bounded to sensitive indicator for Evaluation of an assessment model of urban flood resilience from four aspects: infrastructure, environment, society and economy. Then, it quantifies infrastructure and environmental vulnerability based on GIS, and uses SPSS to quantify social and economic recoverability. Finally, based on k-means clustering of infrastructure and environmental vulnerability and social and economic recoverability, the flood resilience of Calalqa Sub City was evaluated. The general work flow of the study illustrated below figure 3.2

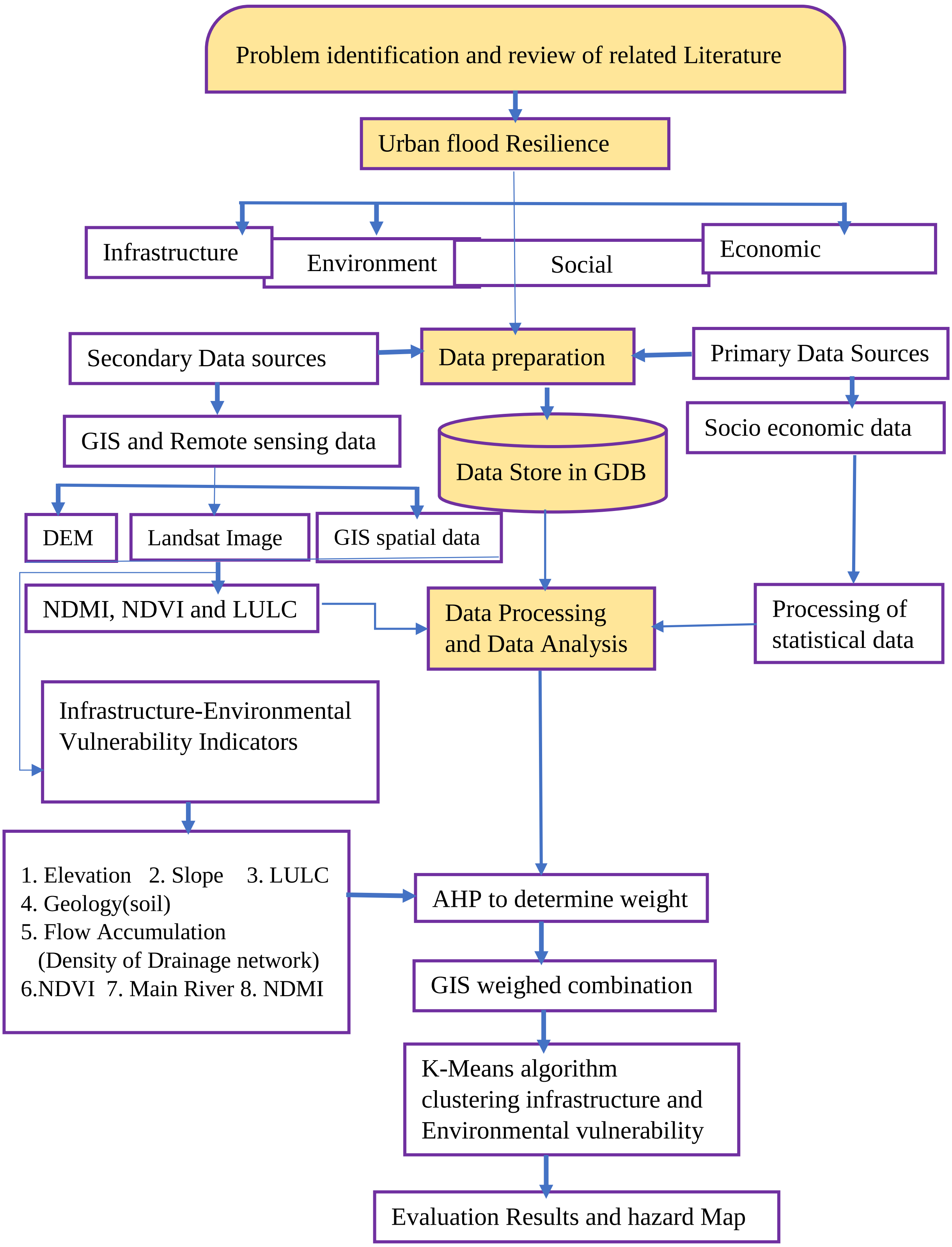

Figure 3.2. Systematic work flow of the study.

(Sources Developed by Author 2023)

3.7.1. Analysing the spatial distribution of the and capacity of the drainage network

Urban infrastructure inventory is paramount to municipalities. This helps to identify what is going on in the boundary of the town, indicates what is lacking and what is in excess. Thus, it is a strong tool to set priorities for each urban infrastructure/utility and helps to update every activity taking place by different bodies within its boundary. In line with this, this study assessed the urban drainage infrastructure in the city including the available resources and the related problems. It also presented various alternatives to manage their resources in a proper way. The study clearly identified the available drainage infrastructure and presented in the body of the study.

Analysing the spatial distribution of an urban drainage system using Geographic Information Systems (GIS) involves several steps to understand the system's components, layout, efficiency, and potential issues. Here's a general guide on how to approach this analysis; Collect relevant spatial data including topographic maps, land use/land cover data, hydrological information, drainage network maps, and infrastructure details.

Drainage Network Mapping: Drainage mapping is used to determine a drainage area and represent the information on a map. Drainage areas are areas where storm water collects: reservoirs, creeks, lakes, streams and rivers. Drainage system maps identify which type of drainage system is being used and where it is located. Marked on the map you may find where surface drainage systems are used to remove excess water via channels or ditches near roadways, slope drainage systems using pipes to manage the water flow, gutter systems to deal with excess storm water or other drainage systems.

3.7.2. Spatial Analysis of urban drainage system

Flow Direction and Accumulation: Use GIS hydrological tools to determine flow direction and accumulation, aiding in understanding how water moves through the drainage system. One of the keys to deriving hydrologic characteristics of a surface is the ability to determine the direction of flow from every cell in the raster. This is done with the Flow Direction tool. This tool takes a surface as input and outputs a raster showing the direction of flow out of each cell. The Flow Accumulation tool supports three flow modelling algorithms while computing accumulated flow. These are D8, Eight-dimension, multiple flow direction and D-Infinity flow methods. If the input flow direction raster is not created with the Flow Direction tool, there is a chance that the defined flow could loop.

Generate detailed reports summarizing the analysis findings, recommendations for improvements, and strategies for enhancing the resilience of the urban drainage system. By leveraging GIS for analysing the spatial distribution of the urban drainage system, stakeholders can gain valuable insights into system performance, vulnerabilities, and optimization opportunities. Integrating spatial analysis with hydraulic modelling and asset management practices enables informed decision-making for effective urban water management.

3.7.3. Monitoring and Evaluation

Urban drainage infrastructures are facing critical challenges due to a lack of integrated asset management, periodic maintenance, improper design, and construction methodologies. Community Monitoring Programs: Implement community-based monitoring programs for flood risks and sustainable development initiatives, empowering residents to track progress and contribute to data collection. Bellows steps are to evaluate the existing system.

Feedback Mechanisms: Establish feedback mechanisms to ensure community input is incorporated into decision-making processes, project design, and policy formulation. By involving the community in flood risk assessment and sustainable urban development initiatives, we can tap into local knowledge, build social capital, and create more resilient, inclusive, and environmentally friendly cities. Empowering communities to take ownership of these initiatives fosters a sense of shared responsibility and promotes collective action towards a safer and more sustainable urban future.

Urban drainage network (UDN) monitoring is an important task whose planning can be related to various purposes, as for example contaminant detection and epidemiological studies. This study proposes two different strategies for the identification of a monitoring system for UDNs. The optimal solution, in terms of location and number of sensors, is firstly addressed using a deterministic approach.

3.7.4. Determine capacity of the drainage network

In this study, we analysed the spatial distribution of the urban drainage network using Geographic Information Systems (GIS) to understand the layout, functioning, and potential vulnerabilities of the drainage system in study area. The capacity of the drains is determined by the flow that can be discharged by the drainage system and the storage available. When hydraulic capacity is insufficient in a certain discharge situation, flooding occurs and water discharges on surface waters.

To determine the capacity of urban drainage the use of land use data and topographic maps is essential for conducting a comprehensive analysis. Land Use Data which used for Identification of Impervious Surfaces can help identify impervious surfaces such as roads, parking lots, and buildings that can contribute to stormwater runoff. High-density urban areas with significant impervious cover can result in increased surface runoff. Zoning Information data can provide insights into the types of land use activities in different areas, allowing for a better understanding of potential pollutant sources and drainage needs.

Urban Growth Patterns Historical land use data can reveal urban growth patterns and changes over time, informing drainage infrastructure planning and design to accommodate future development. Prioritization of Areas for Retrofit can assist in prioritizing areas for drainage system retrofitting or green infrastructure implementation based on land use characteristics and potential environmental impacts.

Terrain Analysis: Topographic maps provide elevation data that is crucial for understanding surface drainage patterns, flow direction, and catchment delineation within the drainage network.

Identification of Drainage Basins: Topographic maps aid in identifying drainage divides and delineating drainage basins, helping to define the contributing areas to different drainage points.

Slope Analysis: Slope information derived from topographic maps helps in determining the slope of terrain, which influences the flow velocity and direction of stormwater within the drainage network.

3.8. Spatial data pre-processing and Vegetation indices for flood hazard

Spatial data is required for the criteria being used for the weighted overlay process. The criteria are; include vegetation indices (NDVI and NDMI), Elevation, main river, Flow Accumulation (Drainage/stream network), Slope, Geology (soil type) and Land use/cover. Raster maps for elevation, slope, and drainage are derived from ASTER DEM. A NDVI, NDMI and LULC map is created from a Landsat 8 image. objective of this thesis is to develop a flood hazard map for the Calalaqa area using remotely sensed data in ArcGIS environment and Erdas Imagine. Site visits across the study area were carried out to ascertain the elements that may have causative influence over flooding in the area. The following elements were deemed to have such influence; Flow Accumulation (Drainage/stream network), Elevation, Slope, Land use/cover, Geology (soil type) and Rainfall intensity (precipitation).

To determine the flood vulnerable areas, Multi Criteria Analysis (MCA) is used. The MCA analysis is done in two phases. The first phase is the use of Analytic Hierarchy Process (AHP), a multi criteria decision tool, to determine the weights of the criteria. AHP constructs a hierarchy of decision criteria using comparisons between each pair of criteria formulated as a matrix. The paired comparisons produce weighting scores that indicates the hierarchy of importance of selected criteria. The second phase then incorporates the determined weights in a weighted overlay process to produce the flood hazard map.

3.8.1. Vegetation indices (Normalized Difference Vegetation Index)

The Normalized Difference Vegetation Index (NDVI) is an indicator that uses the red and near-infrared spectral bands (Equation (2)). It is one of the most well-known and used vegetation indices and it is highly associated with vegetation content. High NDVI values correspond to areas that reflect more in the near-infrared spectrum. Higher reflectance in the near-infrared corresponds to denser and healthier vegetation (GU, 2019).

$$NDVI = \frac{(Band\ 5 - Band\ 4)}{(Band\ 5 + Band\ 4)} \quad \text{……………………………………………………….}(2)$$

The post-flood image was subtracted from the pre-flood image to generate a new difference image to serve as a measure of absolute change between captured images. In the new raster, higher values represent areas of greatest change (high flood severity) and low or negative numbers representing non-flooded areas.

3.8.2. Vegetation indices (Normalized Difference Moisture Index)

Normalized Difference Moisture Index (NDMI) is used to determine vegetation water content (Equation (3)). It is calculated as a ratio between the band 5 and Band 6 values (USGS, 2019). Generally higher value of NDMI specifies the presence of more soil moisture under massive aquatic bodies. Vegetation water content and soil moisture content are determined by it.

$$NDMI = \frac{(Band\ 5 - Band\ 6)}{(Band\ 5 + Band\ 6)} \quad \text{…………………..…………………..………………..…. }(3)$$

The high value of NDMI = 0.25 and above classified as very low and value of NDMI = 0.01 classified as very high rank.

3.8.3. The Stream Network (Flow Accumulation)

The stream network is derived from the ASTER DEM. Figure 3.3 shows the conceptual overview of watershed and stream network delineation.

For watershed delineation, a depression-less DEM is needed hence the sink tool in ArcGIS hydrology is used to locate sinks in the DEM and the fill tool is used to fill the identified sinks. Flow direction tool is then applied to compute the direction that water would flow for every cell and flow accumulation calculates the number of cells flowing into each cell of the filled DEM. Areas with very high values may possibly be perennial streams or rivers, areas with lower values may be sporadic streams. The Flow Accumulation grid allows for the determination of areas draining to points on the DEM. The Basin tool is then used to create watersheds. The Basin tool finds its own pour points and creates watersheds for the whole map.

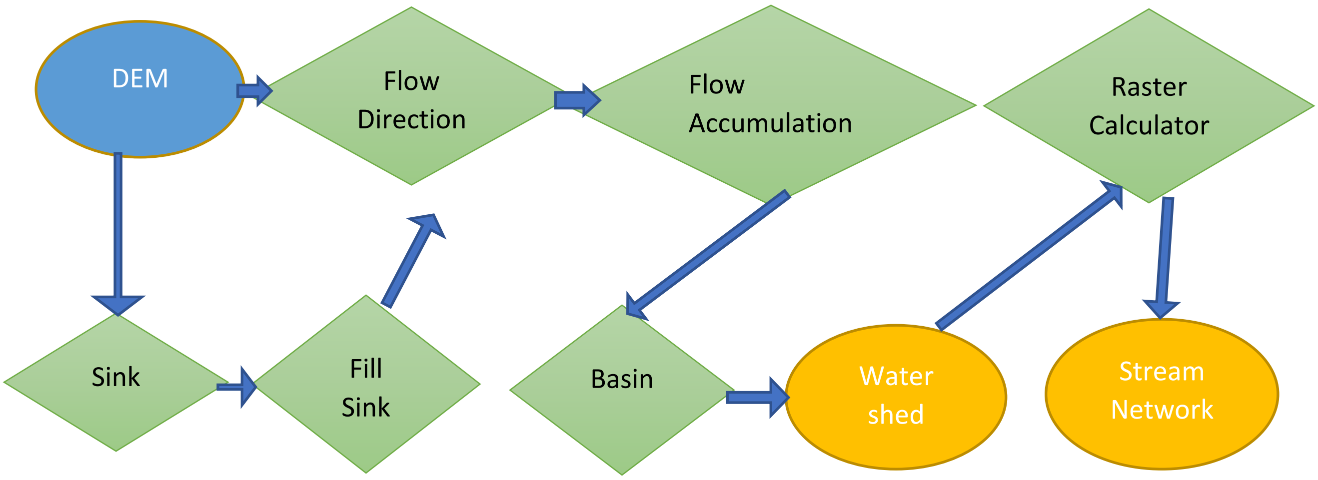

Figure 3.3: Flow chart for watershed and stream network delineation

To determine the stream network a conditional statement is applied to the flow accumulation raster. The idea is to reclassify all cells that meet a certain accumulated flow threshold to be 1, and all other cells to be no data. The threshold used for this analysis is 3098 which implies that all cells with a value greater than 3098 are reclassified as 1. The threshold of 3098 was chosen because it gave the best representation of the drainage basin.

The conditional statement “Con ("FlowAcc_Flow1" > 3098, 1)” is created with the Raster Calculator. This produced a detailed stream network raster for the area covered by the Flow Accumulation grid which is then reclassified to the predefined rankings. In the reclassification of the flow accumulation grid, flow accumulation between 126765705.9 and 220537597 were deemed to have the highest flood causing influence and hence was assigned the ranking “very high”. Flow accumulations between 63382852 and 126765705.9 were deemed to have the next highest flood causing influence and therefore assigned the ranking of "high". Flow accumulations between 24311231.2, 5209549.5, and 0 were then subsequently assigned moderate, low and very low rankings respectively (table 3.3).

Table 3.3: Flow Accumulation ranking Flow accumulation

Flow accumulation	**Ranking**	**% Weight 12**
126765705.9 – 220537,597	Very high	
63382852 – 126765705.9	High	
24311231.2 – 63382852	Moderate	
5209549.5 – 24311231.2	Low	
0 – 5209549.5	Very low	

3.8.4. Elevation and Slope

The elevation and slope are determined from the ASTER DEM using surface analysis tools under the spatial analyst tool bar in ArcGIS. Contours of the study area are extracted from the DEM and this is used to generate the slope and elevation maps. The steepness of the slope affects the flow and inundation of a particular area. Low-lying areas with gentle slope angles have the tendency to be inundated first as compared to areas with steep slope angles during flooding. Flat terrain decreases water runoff and this causes high infiltration where there is open soil, or stagnation where there is impermeable surface leading to water logging condition.

The slope map is classified into two classes using Natural Breaks (Jenks) distribution (figure 3.4, table 3.4). Class 1: 0^o and class 2: 0^o-61^o and these classes are then assigned into the predefined rankings.

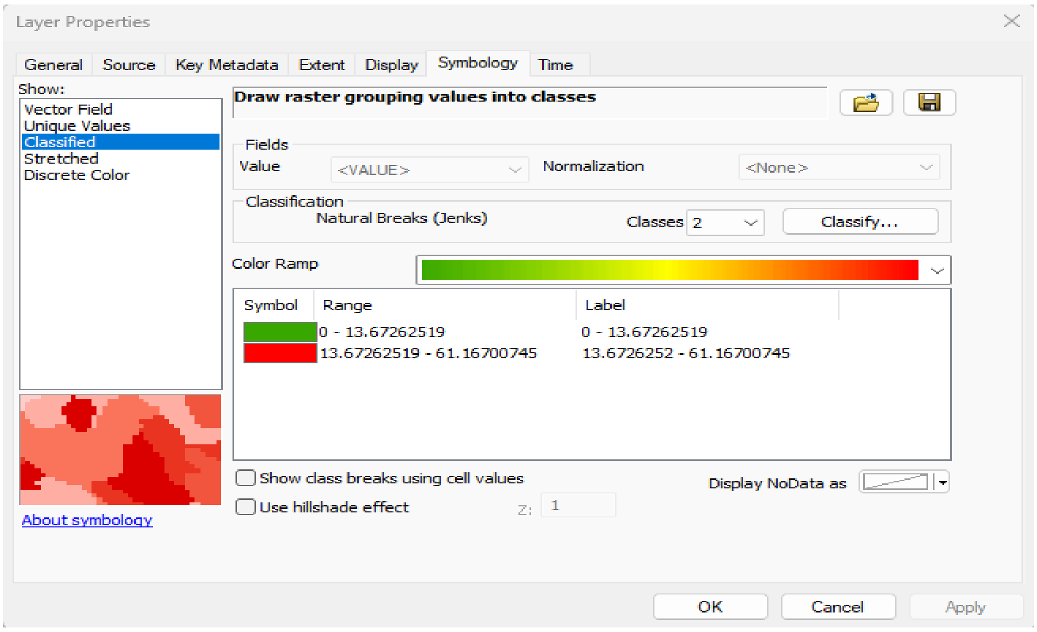

Figure 3.4: slope classification

The elevation map is classified into five classes using Natural Breaks (Jenks) distribution because it identifies real classes within the data and creates choropleth maps that have accurate representations of trends in the data (R. Jones, 2016). class 1: 1848 - 1929m; class 2: 1929 - 2032m; class 3: 2032 - 2201; class 4: 2201 - 2430; class 2430 – 2875 and these classes are then reclassified into the predefined rankings (figure 3.5, table 3.5).

The slope map is reclassified into two rankings, very high and high, based on the classes obtained from the Jenks distribution.

Table 3.4: Slope ranking

Slope º	**Ranking**	**% Weight 25**
0	Very high	
0 – 61	High	

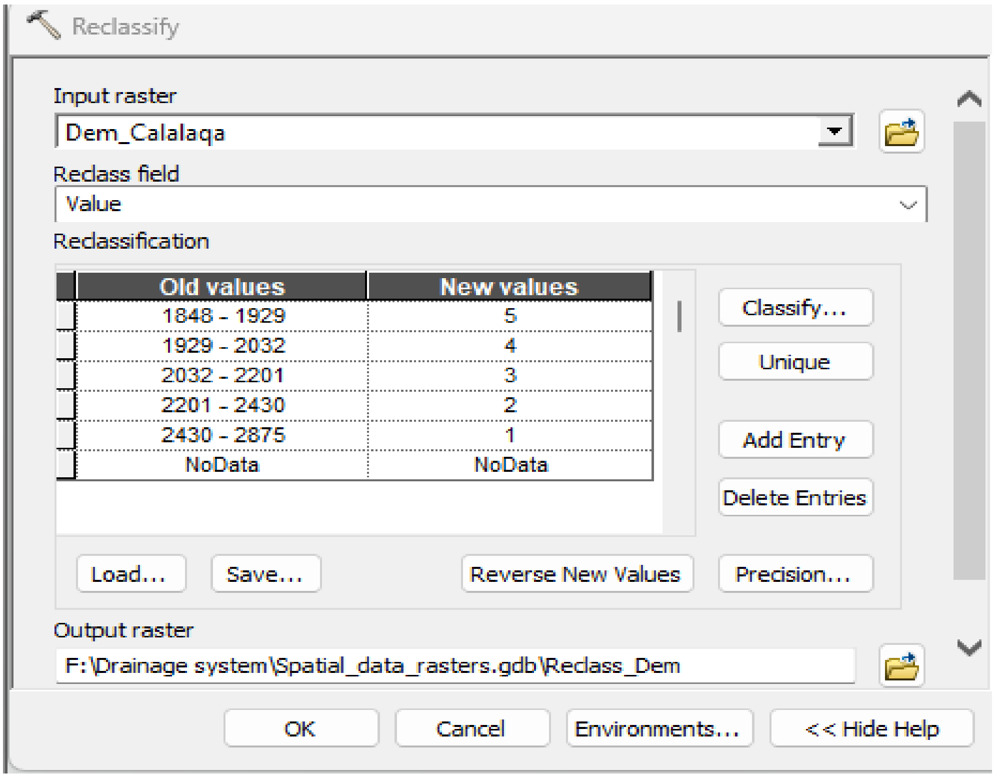

Figure 3.5: reclassification process

Table 3.5: DEM ranking

DEM (m)	**Ranking**	**% Weight 27**
1848 - 1929	Very high	
1929 - 2032	High	
2032 - 2201	Moderate	
2201 - 2430	Low	
2430 - 2875	Very low	

3.8.5. Land Use/Cover

The land use/cover map of the study area is classified from a Landsat-8 OLI satellite imagery acquired on 02 April, 2024. Iso cluster Unsupervised classification was carried out to generate the land use/cover map. In unsupervised classification, clusters are created from pixels with similar statistical properties (Environmental Systems Research Institute, 2016). The created clusters have no definite meaning and classification is done by the user. Thirty spectral classes are defined for the classification of the image. This is because although six land cover classes are to defined, these classes may contain a range of spectral identities. The six cover classes are color coded and the colors for the thirty spectral classes are changed to fall into one of the six colors. This defines that pixel as belonging to that feature.

Unsupervised classification was used for the land use classification because training areas defined under supervised classification classified some features in the wrong class. The created LULC map included six features namely; Farm Land, Open forest, water, Builtup, vegetation and bare land/ground.

This is then reclassified for the overlay analysis. The urban land cover is deemed to be the cover highest prone to flooding because of all the impermeable surface and therefore assigned the rank of 'very high'. Vegetation and bare ground land covers are both deemed to be the next highest covers prone to flooding because of their compacted nature and are assigned the rank of 'high'.

Table 3.6: Land cover ranking

Land use/cover	**Ranking**	**% Weight 14**
Open Forest	Moderate	
Water	Very Low	
Urban built-up	Very high	
Vegetation	High	
Bare land	High	
Farm land	Low	

The Open forest and water land covers are assigned moderate and low rankings respectively (Table 3.6). The LULC statistics (Table 3.7, show that majority of the study area is covered by urban land.

Table 3.7: Land Cover Statistics

S/N	Class Name	Area in Ha
1	Bare land	1260.924
2	Farm land	6046.157
3	Open Forest	1065.665
4	Urban Built-up	4690.726
5	Vegetation	3562.349
6	Water bodies	556.4874

3.8.6. Main River Stream

A river data from ethio-GIS shapefiles. River factors Lower-lying areas are prone to flooding and can experience more intense flooding depending on how fast water arrives, how long it takes to recede, and if additional rain in the area makes it hard for the land to absorb excess water. Living near water can increase the risk of flooding, erosion, and water-related hazards such as hurricanes, storms, and tsunamis. Additionally, proximity to water bodies may attract pests like mosquitoes and increase humidity levels.

Distance from the river is considered as an important parameter in flood risk mapping as areas located in close proximity to the river always remain under threat of probable hazardous effect of flood. In the present study, buffer extension of Arc GIS 10.8 was used to create buffer zone along both sides of the river at 1.5 km interval. Rank from 1 to 5 was assigned to the buffer classes to create a reclassified buffer map of the lower course of the main River. The zone which represents the area within 1.5 km along the River was assigned with rank 5 as these are threatened by inundation even during low to medium scale flood; conversely, the zone at a distance of 6-10 km was assigned with rank 1.

3.8.7. Geology (Soil Type)

The geological map for the study area was downloaded from FAO,1984. The geology map is reclassified into five classes for the weighted overlay process based on their flooding influence. According to the geological surveys department and the centre for policy analysis, the soil types in study area has about the same potential for flooding since most of the soil types are variations of gravel and sand mixed with high content of clay with a thin organic layer.

Table 3.8: Soil rankings

Geology/soil class	Rank	**% Weight 8**
Vertosol (VR)	Very High	
Combosol (CM)	High	
Leptosol (thin)	Moderate	
Leptosol (LP) Upland	Low	
Luvisol (LV)	Very Low	

The study area was therefore reclassified into very high, high and low rankings of flood causing capacity based on the soil's infiltration ability (table 3.8).

3.9. Multi Criteria Analysis

Multi-Criteria Analysis is a structured decision-making tool used to solve complex problems. MCA describes any deliberate and organized approach used to determine overall preferences among alternative options with a view to ranking them from the most important to the least important. The outcome of MCA is a set of weights for the various alternatives. There are different techniques of MCA and some examples are Aggregated Indices Randomization Method (AIRM), Analytic hierarchy process (AHP), Analytic network process (ANP), Best worst method (BWM), Characteristic Objects Method (COMET), Choosing by Advantages (CBA), etcetera. This thesis employs the Analytic hierarchy process (AHP) technique because that is the technique which, based on research, is widely used for flood analysis.

3.9.1. The Analytic Hierarchy Process

The Analytic Hierarchy Process was presented by (Saaty,1977) as a multi-criteria decision-making approach in the 1970s as a way of dealing with resource and asset allocation. The AHP is a tool which can be used to solve a combination of complex qualitative, quantitative, and occasionally conflicting decision problems. Saaty developed the Pair-wise Comparison Method which is used in the AHP to obtain the weights or priority vector of the selected criteria. To make the comparisons, a scale of numbers in needed which shows how many times one element is more important over another element with which it is being compared (saaty,2008). Table 3.10 shows the scale of numbers.

Table 3.9: The fundamental scale of absolute numbers (Saaty 2008) Intensity of Importance

no	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

A decision problem is decomposed into a hierarchy of goal, criteria and alternatives in procedure. Data is then collected from decision-makers for a pairwise comparison of criteria on a scale as described above. A square matrix is created from the pairwise comparisons of various criteria. For flood analysis, the decision problem is decomposed into a hierarchy of goal and criteria.

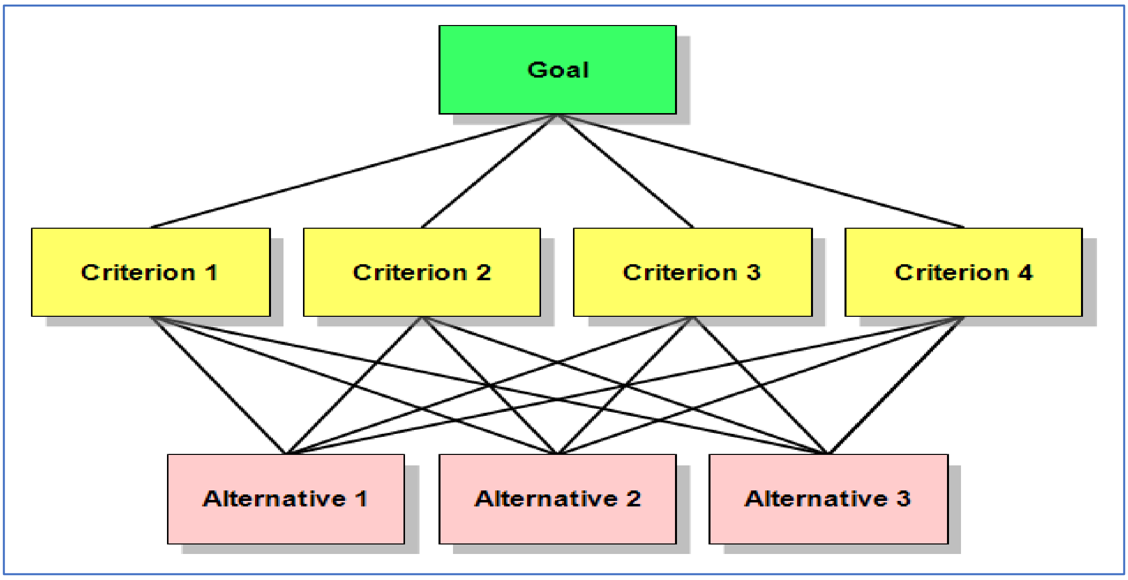

Figure 3.6: AHP process

The goal for this thesis is to develop a flood hazard map and the criteria to be used are elevation, slope, Main river, land cover, soil type and drainage process in AHP. Priorities of the decision criteria are then estimated. Subjective priorities according to decision makers' preferences, are transformed to computable values by means of the pairwise comparison matrix which makes the pairwise comparison matrix very important.

3.9.2. Pairwise Comparison Method

For this thesis, the elements deemed to have causative influence over flooding in the study area are used as the criteria for analysis. Based on the scale above, a matrix is constructed for the selected criteria

C1 = Slope

C2 = Elevation

C3 = NDMI

C4 = Main River

C5 = Land use/cover

C6 = Flow Accumulation (Drainage/stream network)

C7 = NDVI

C8 = Geology (soil type)

Table 3.10: Pairwise comparison matrix C

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	1.786	5	1.887	2.5	5	6.667	3.333
C2	.56	1	2	4	3.846	4	6.667	6.667
C3	.2	.5	1	1.667	2	2.273	1.818	2.857
C4	.53	.25	.6	1	1.515	2	2.222	3.333
C5	.4	.26	.5	.66	1	6.667	2.857	5
C6	.2	.25	.44	.5	.15	1	1.818	5
C7	.15	.15	.55	.45	.35	.55	1	1.667
C8	.3	.15	.35	.3	.2	.2	.6	1
SUM	3.34	4.346	10.44	10.464	11.561	21.69	23.649	28.857

In constructing the pairwise comparison matrix, each criterion is compared to one another and the decision maker decides which of the two criteria is likely to have more influence in flooding the area. If criteria A has the same influence as criteria B, the pair receives an index of 1. If criteria A has more influence than criteria B, then the pair receives an index from 9 to 2. The reciprocal for the index is used for the reverse comparison. Once the pairwise comparison matrix is constructed, the matrix is normalized so that each column sums up to one.

This is done by dividing each element in every column of the matrix with the sum of that column. Next, the average across the rows is computed to give the priority vector or the Criteria Weights {W}. This denotes the comparative ranking of importance attached to the criteria being compared. Based on the experience and judgement of residents (Experts) in the study area, values were assigned to construct the pairwise matrix. The final values in the matrix were decided on after three iterations to arrive at the lowest consistency ratio of **0.086** In practice, individual decisions are never the same and do not agree perfectly therefore, the degree of consistency achieved in the scaling of the matrix is measured by a Consistency Ratio (CR) which shows the probability that the scaling were generated randomly. A CR less than or equal to 0.1 indicates an acceptable reciprocal matrix and a ratio over 0.1 indicates that the matrix should be re-examined.

Re-examining the matrix involves locating inconsistent decisions with regards to the importance of criteria and revising these decisions by comparing the pair of criteria again.

Calculating Consistency Ratio (CR)

First determine the weight sum vector {Ws}

$$\{Ws\} = [C]\{W\} \quad \ldots(4)$$

Where C is the pairwise comparison matrix and W is the priority vector

The eigen value λ is then determined

$$\lambda = \frac{\{Ws\} * \{1/W\}}{n} \quad \ldots(5)$$

Where n is the number of criteria. After that, a Consistency Index (C.I.) is computed using the following formula

$$\mathbf{C.I.} = \frac{\boldsymbol{\lambda - n}}{\boldsymbol{n - 1}} \quad \ldots(6)$$

The Consistency Ratio (C.R.) is then calculated to determine if the comparisons are consistent or not.

$$C.R. = \frac{C.I}{R.I} \quad \ldots(7)$$

Where R.I. is the Random Inconsistency index

3.10. The Weighted Overlay Process

The weighted overlay process consists of three conceptual steps. First, each raster layer is assigned a percentage weight (the criteria weights determined in the AHP), to underscore the relative importance of each layer in the analysis. Second, the values within each raster layer are ranked (importance scale) to allow comparison of the different types of information in each raster layer and then third, all raster layers in the analysis are overlaid (ESRI,2016). The ranking value of individual raster cells is multiplied by its layer weight and totaled with the values of other raster cells it overlays. In ranking step, every criterion under consideration was ranked in the order of preference. There are two typical ways of ranking; straight ranking (that is; most important = 1, least important = 9) or the inverse ranking (most important = 9, least important = 1). The ranking applied to this analysis corresponds to the level of flooding, which are, very high = 5; high = 4, moderate = 3; low = 2 and very low = 1.

3.10.1 Weighted Overlay Analysis

The weighted overly tool in spatial analyst is applied for the analysis. The six reclassified raster layers are weighted based on the weights of the pairwise comparison process and then combined based on the assigned rankings used in the reclassification. The cell values of each input raster are multiplied by the raster's weight then the resulting cell values are added to produce the final output raster (ESRI, 2016). The output raster is a flood hazard map that shows which areas falls within the different levels of flooding defined above.

3.11. IMAGE PRE-PROCESSING

The image is prepared by sub-setting it to get the study area. Once the study area is obtained, the image is then pre-processed through quick steps and its downloaded from USGS website. The downloaded image was used for LULC. This is then followed by Techniques for Image Pre-processing.

The choice of techniques depends on the nature of the image and the application. Here are a few techniques to improve image quality and suitability. The quick steps for Image corrections are;

Noise Reduction: Noise in an image can be caused by various factors such as low light, sensor noise, and compression artifacts. Noise reduction techniques aim to remove noise from the image while preserving its essential features. Some common noise reduction techniques include Gaussian smoothing, median filtering, and wavelet denoising.

Enhancement: Contrast enhancement techniques aim to increase the contrast of an image, making it easier to distinguish between different image features. These techniques can be helpful in applications such as medical imaging and surveillance. Some standard contrast enhancement techniques include histogram equalization, adaptive histogram equalization, and contrast stretching.

Image Resizing: Image resizing techniques are used to adjust the size of an image. Resizing can be done to make an image smaller or larger or to change its aspect ratio. Some typical image resizing techniques include nearest neighbour interpolation, bilinear interpolation, and bicubic interpolation.

Colour Correction: Colour correction techniques are used to adjust the colour balance of an image. Colour correction is important in applications such as photography, where the colour accuracy of an image is critical. Some common colour correction techniques include gray world assumption, white balance, and colour transfer.

Feature Extraction: Feature extraction techniques are used to identify and extract relevant features from an image. These features can be used in object recognition and image classification applications. Some standard feature extraction techniques include edge detection, corner detection, and texture analysis.

CHAPTER FOUR

4. RESULT AND DISCUSSION

This chapter presents assessment of the urban drainage system in Calalqa Sub city and assess its resilience to effectively manage stormwater and prevent flooding. The data collected from different sources are interpreted in this chapter. Flood hazard analysis was done based on mapping environmental factors making the area vulnerable for flood hazards. These environmental factors include terrain, slope, flow accumulation (Stream network), main rivers, geological map (Soil types) and land use land cover (LULC) scenarios computed based on the data obtained from remotely sensed imageries. In fact, in order to minimizes the risks of methodological errors, accuracy assessment was employed to find out those errors so as ensure reliability of the produced LU/LC maps and the overall assessment results. The classified maps were assessed and compared with a referenced data.

Additionally, Examine Causes and impacts of flooding hazards in study area Community perception, To Designate the measures taken by the community and the government in mitigating flooding hazards in the area socio economic data was analysed and discussed in this chapter.

4.1. Multi Criteria Analysis Results

The results from the pairwise comparison process is computed as shown in previous chapter and Percentage for each factor are; NDVI 5%, NDMI 4%, Elevation 25%, slope 27% main river 5%, Stream (natural drainage) 12%, LULC 14%and for geology(soil) 8% assigned as criteria weights. This is an indication of the level of influence each criterion has on flooding of the study area. C1 = Slope has the most influence of 27 percent and C3= NDMI has the least influence of 4 percent.

4.1.1. Normalized Difference Vegetation index (NDVI)

The results show NDVI calculated using (equation1) was illustrated in figure 4.1. generally, NDVI values range from -1.0 to 1.0, with negative values indicating clouds and water, positive values near zero indicating bare soil, and higher positive values of NDVI ranging from sparse vegetation (0.1 - 0.5) to dense green vegetation (0.6 and above). As shown in map below Red and orange pixels represent areas with no vegetation. Yellow pixels represent areas with low to moderate vegetation. Green pixels represent areas with high vegetation density and vigor.

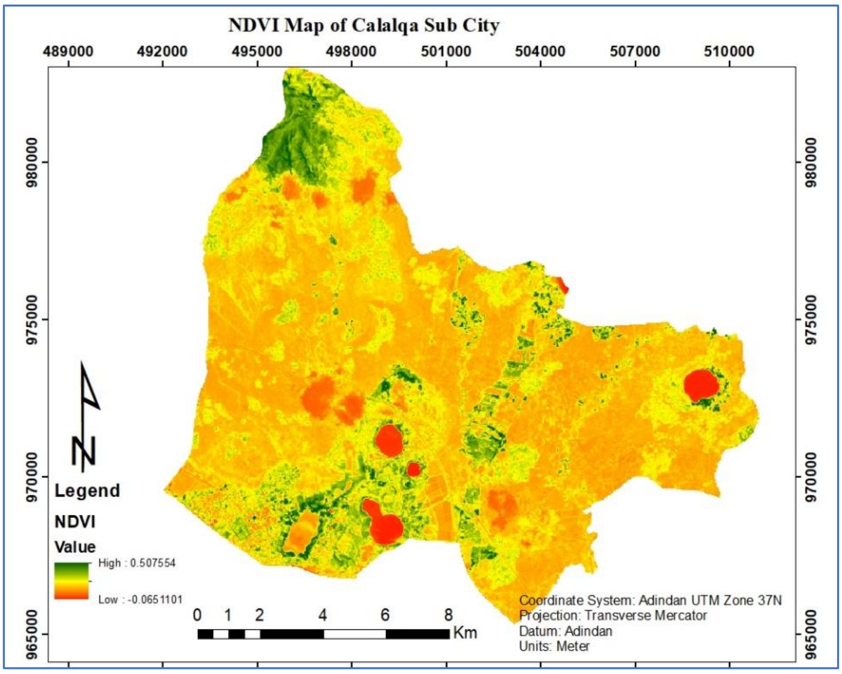

Figure 4.1. NDVI map of study area.

(Source: Computed based on the data obtained from, USGS Landsat 8, 2024)

The status of Flood was evaluated in relation to the range of NDVI which were classified in to five class or categorized.

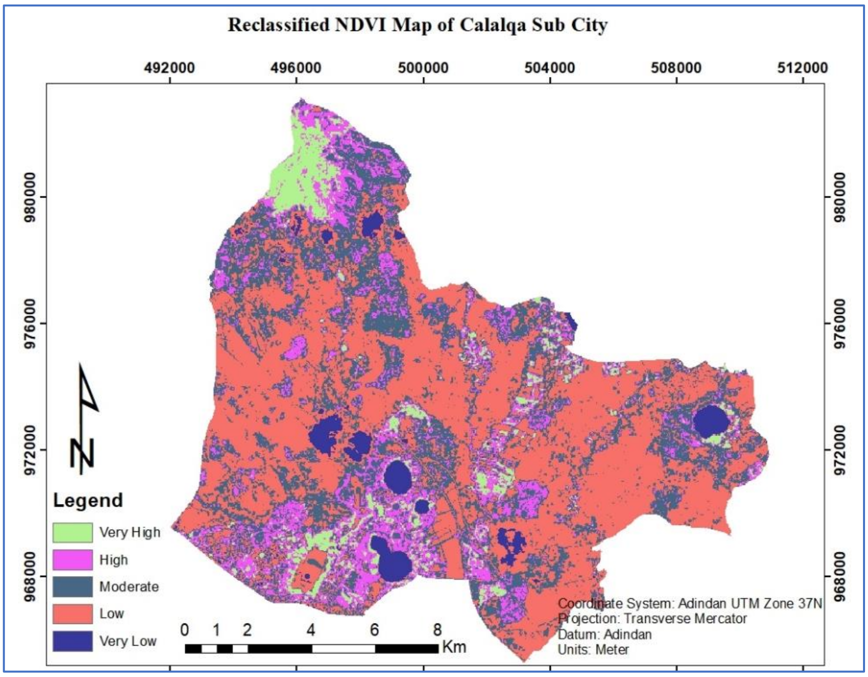

Figure 4.2. Reclassified NDVI Map of study area.

(Source: Computed based on the data obtained from, USGS Landsat 8, 2024)

The classified NDVI show value (-0.067) – 0.051 = very high ranked, value 0.05 – 0.11=High, value 0.11- 0.16=Moderate, value 0.16 - 0.23= Low, and value 0.23 – 0.50 ranked as Very low. The results of reclassification of NDVI in five class were illustrated in Figure 4.2.

4.1.2. Normalized Difference Moisture Index (NDMI)

It is important to keep in mind that NDMI values vary throughout the growing season because the plants' reflectance is slightly different for every phenological stage. There also exists an interesting correlation between NDMI and NDVI. Water stress indicated by the NDMI values can be confirmed by a significantly lower than average NDVI. Total canopy cover, no water stress/waterlogging

The NDMI range is -1 to +1, where the lowest values (white to pale brown) indicate low vegetation water content, and the highest ones (in blue) correspond to high water content. In other words, decrease in NDMI will indicate water stress, while abnormally high NDMI values could signal waterlogging**.** The high value and low range value of NDMI shown in figure 4.3.

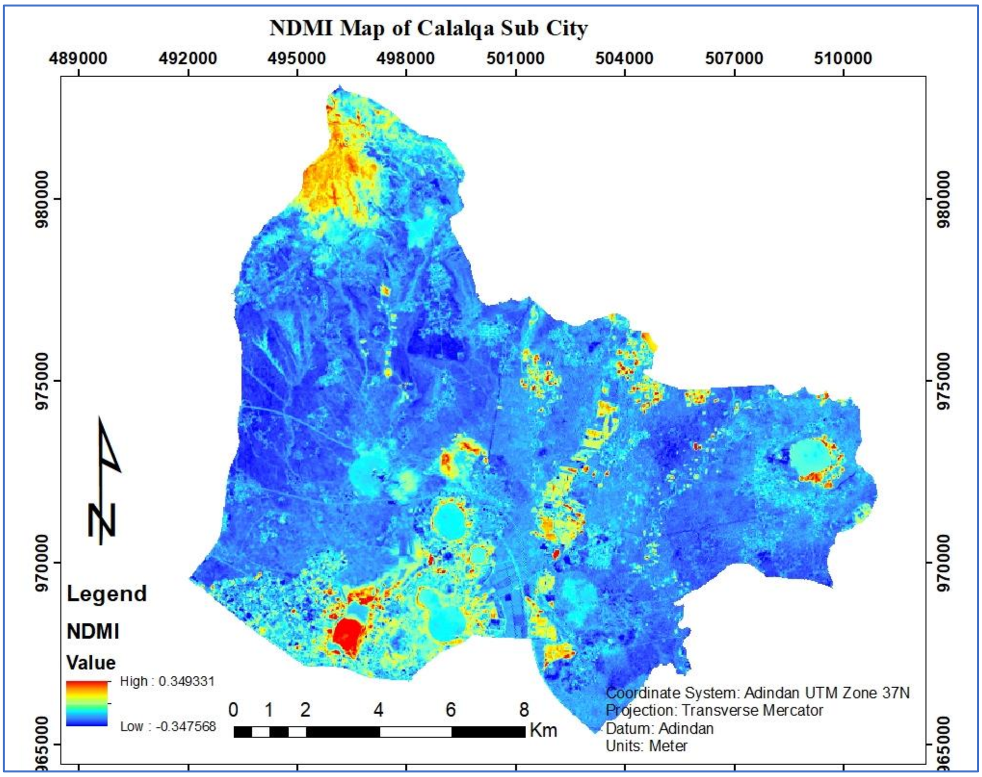

Figure 4.3 NDMI map of study area.

(Source: Computed based on the data obtained from, USGS Landsat 8, 2024)

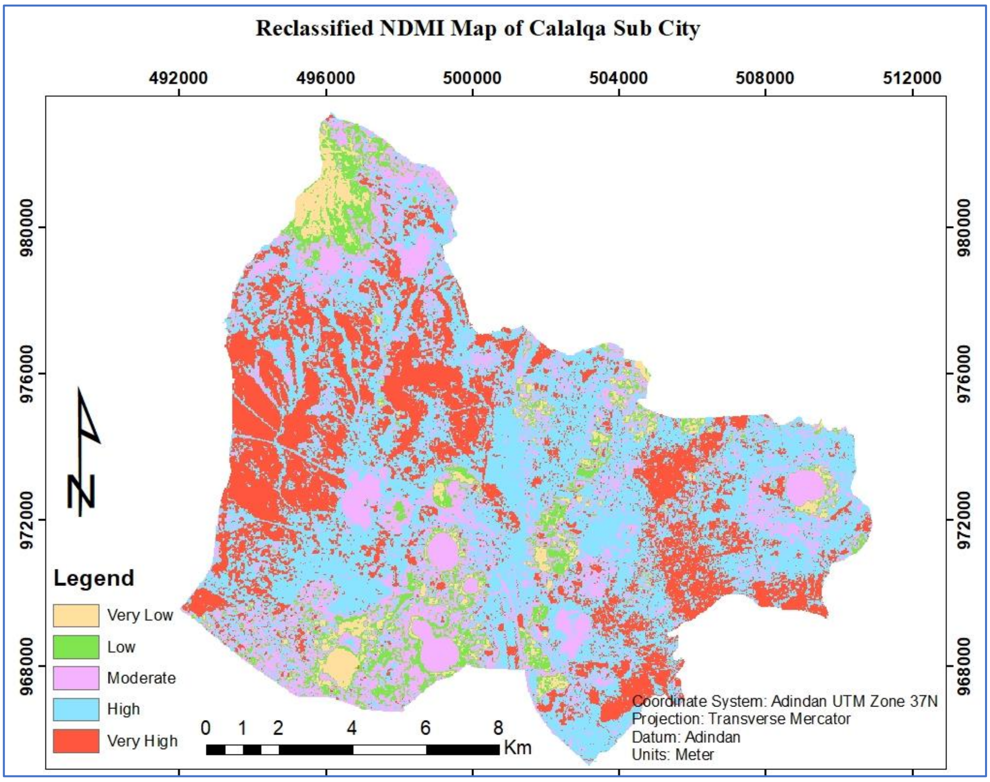

Figure 4.4 Reclassified NDMI map of study area

(Source: Computed based on the data obtained from, USGS Landsat 8, 2024)

The classified map shown (figure 4.4) based on standards of NDMI Interpretation described as; -1 – -0.8 Bare soil,-0.8 – -0.6 Almost absent canopy cover,-0.6 – -0.4 Very low canopy cover,-0.4 – -0.2 Low canopy cover, dry or very low canopy cover, wet,-0.2 – 0 Mid-low canopy cover, high water stress or low canopy cover, low water stress,0 – 0.2 Average canopy cover, high water stress or mid-low canopy cover, low water stress, 0.2 – 0.4 Mid-high canopy cover, high water stress or average canopy cover, low water stress, 0.4 – 0.6 High canopy cover, no water stress,0.6 – 0.8 Very high canopy cover, no water stress,0.8-1 total canopy cover which no water logging.

4.1.3. Elevation criteria

The highest areas of the study area are found in the northwest part of the area, which is parts of mountain range. This means the streams flow northwest to southern and eastern direction. The highest peak of in its northern area, and the altitude is about 2,875 meters Above msl and the lowest point of area 1851 meters Above msl at the outlet of the drainage in the middle of town surround lakes. The steepness of the slope affects the flow and inundation of a particular area. Low-lying areas with gentle slope angles have the tendency to be inundated first as compared to areas with steep slope angles during flooding. Flat terrain decreases water runoff and this causes high infiltration where there is open soil, or stagnation where there is impermeable surface leading to water logging condition.

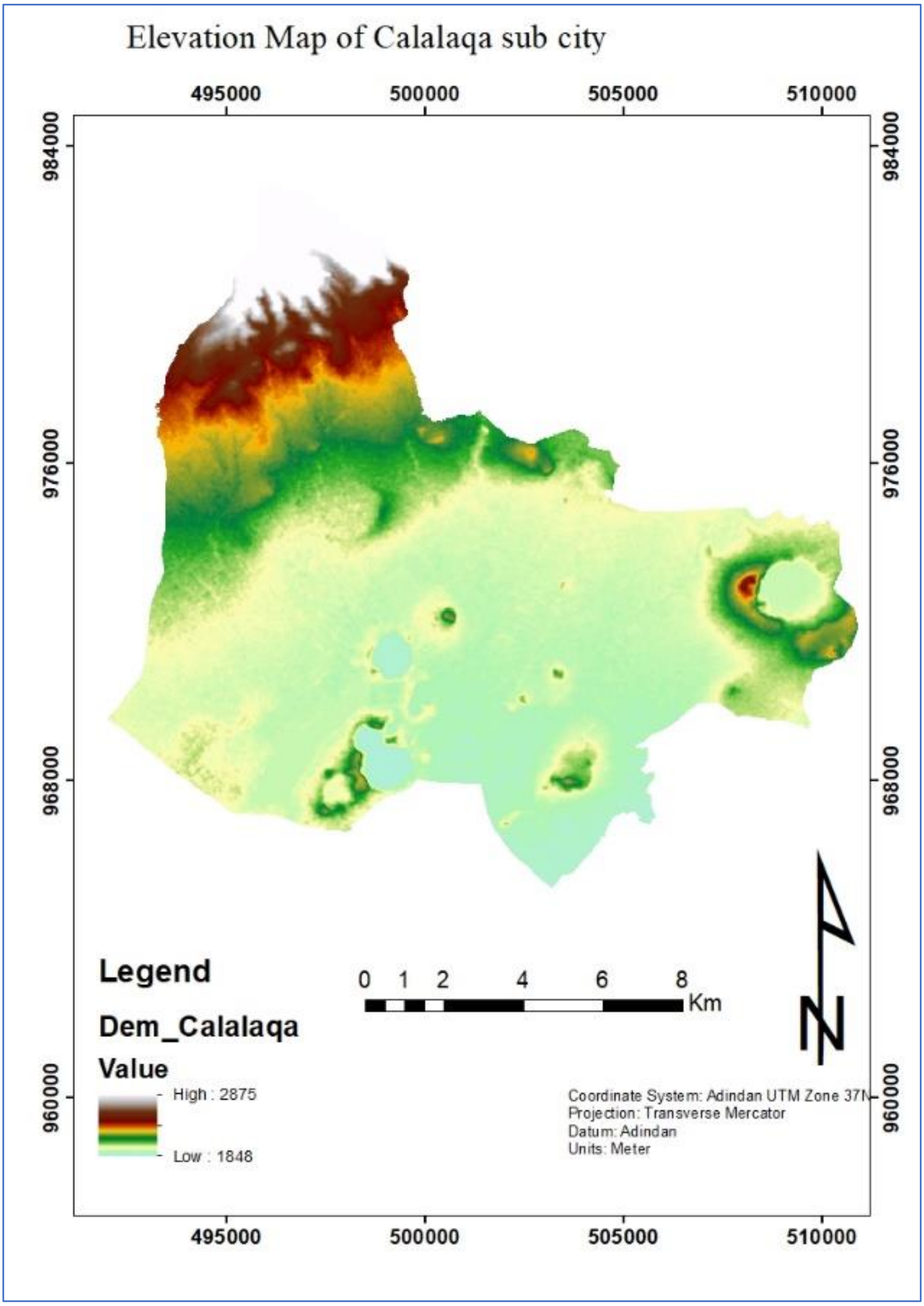

Figure 4.5. Elevation map of study are

(Source: Computed based on the data obtained from ASTER DEM, 2024)

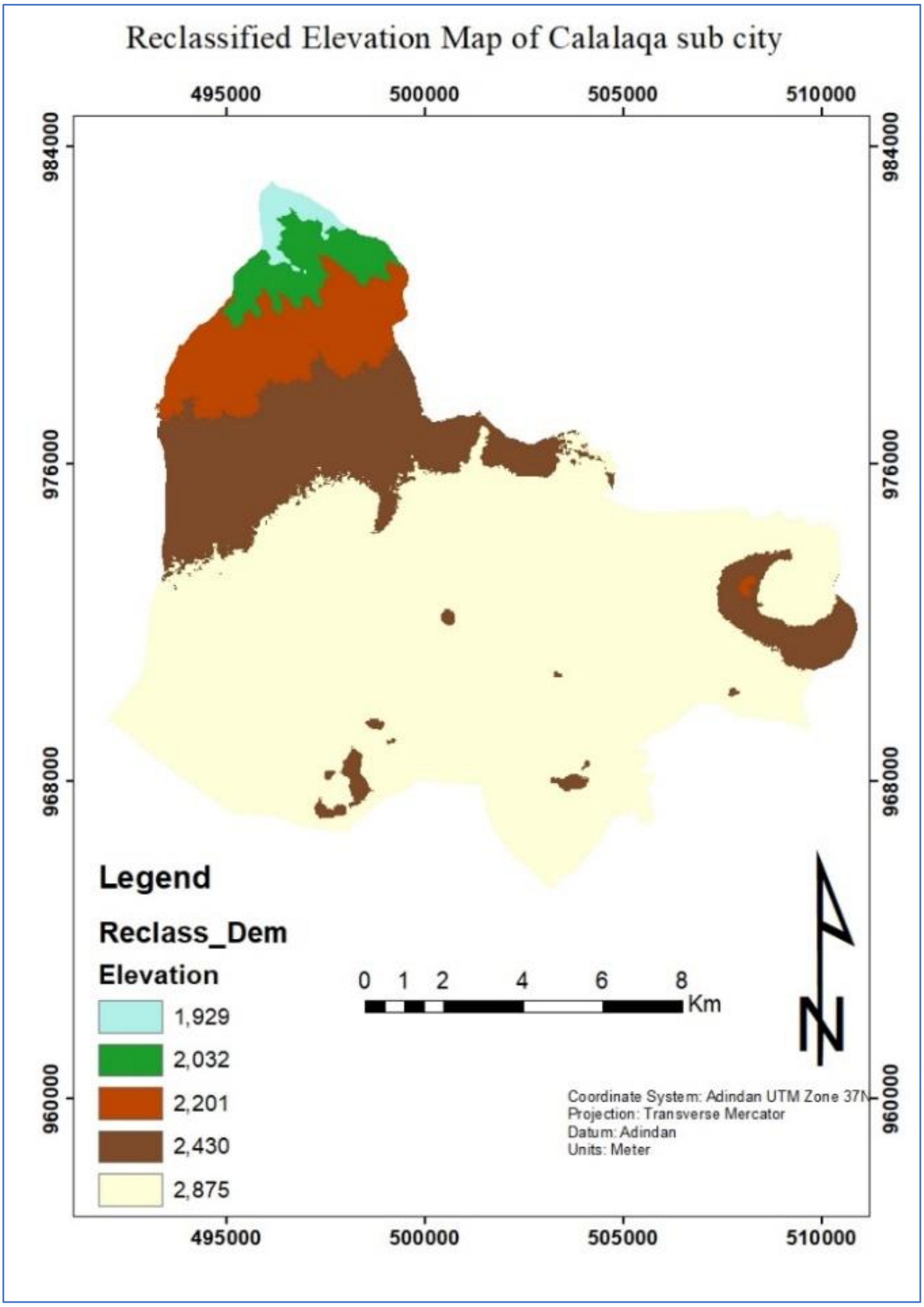

Figure 4.6: reclassified DEM

(Source: Computed based on the data obtained from ASTER DEM, 2024).

The elevation map is classified into five classes using Natural Breaks (Jenks) distribution because it identifies real classes within the data and creates choropleth maps that have accurate representations of trends in the data. class 1: 1848 - 1929m = very high; class 2:

1929 - 2032m = High; class 3: 2032 – 2201m = Moderate; class 4: 2201 – 2430 = Low and class 2430 – 2875 and these classes are then reclassified into very low rankings.

4.1.4. Slope Reclassification

Land slope is essentially the gradient or inclination of the land. A steep slope refers to a sharp incline; while a gentle slope is referring to a slight incline. Slope is a measure of terrain steepness that is, the degree to which land is not flat/horizontal. Slope affects the construction sustainability of in different area such as the place where with high slope (steep). In other word slope is another means of describing topography for a given area. It is a measure of terrain steepness that is, the degree to which land is not horizontal. The range of slope values in degree is 0 to 90. For percent rising, the range is 0 for near infinity. A flat surface is 0 percent, and as the surface becomes more vertical, the percent rises becomes increasingly larger. The categorization of an area in different slope classes can be used for different civic works such as for planning drainage, road construction, housing and etc…in this analysis map, slope is measured as percentage rises classified in to 5 different ranges.

Table 4.1. Classification of Slope map area coverage and percentage

Slope class and vulnerability level	area in ha	Percentage%
0-5 (Very low)	247.53	1.46
5-8 (Low)	651.37	3.83
8-17 (Moderate)	1502.93	8.84
17-30 (High)	2295.99	13.51
30-61 (Very High)	12300.03	72.36
Total	16997.85	100.00

(Source: Computed based on the data obtained from ASTER DEM, 2024)

In case study area, as shown in Figure 4.2 and Table 4.1, the area is characterized by a slope ranging from 0 to over 61 degree. This is one of the physical factors making the area vulnerable for flooding. Particularly, the areas in > 61-degree slope are very highly vulnerable for flooding. This adverse factor, together with other factors like paving and dumping of wastes in river courses, leads the area to the situation of high vulnerability to flooding hazards. The total area which is found to be very highly vulnerable to flooding is about 12300.03 ha, accounting for about 72% of the total area.

Moreover, the combination of Table 4.1 and Figure 4.7 show that about 13.5 % of the study area is found in the highly vulnerable area with slope ranging between 17-30 degree. About 8.84% of the area is found sloping environment with slope ranging between 8-17%. This area is rather vulnerable to erosion. The large coverage of the slope of the study area covered by flat and gentle slopping is between 0-15 degree, receiving water from the upper area of runoff, putting the area at its vulnerable position for flooding hazards.

Figures 4.7 and 4.8 below are the slope map and reclassified slope map of the study area. Elevation and slope play essential roles in the flood vulnerability of a terrain. The slope influences the amount of surface runoff or subsurface drainage, infiltration and the direction of flow. Slopes with low gradients are extremely susceptible to flood occurrences since flat terrains allows for waterlogging conditions. The slope was classified using natural breaks and it can be noticed that majority of the study area is nearly flat. The flat nature of the terrain of the study area coupled with the high clay content of the soil, leads to rapid accumulation of rain water leading to floods.

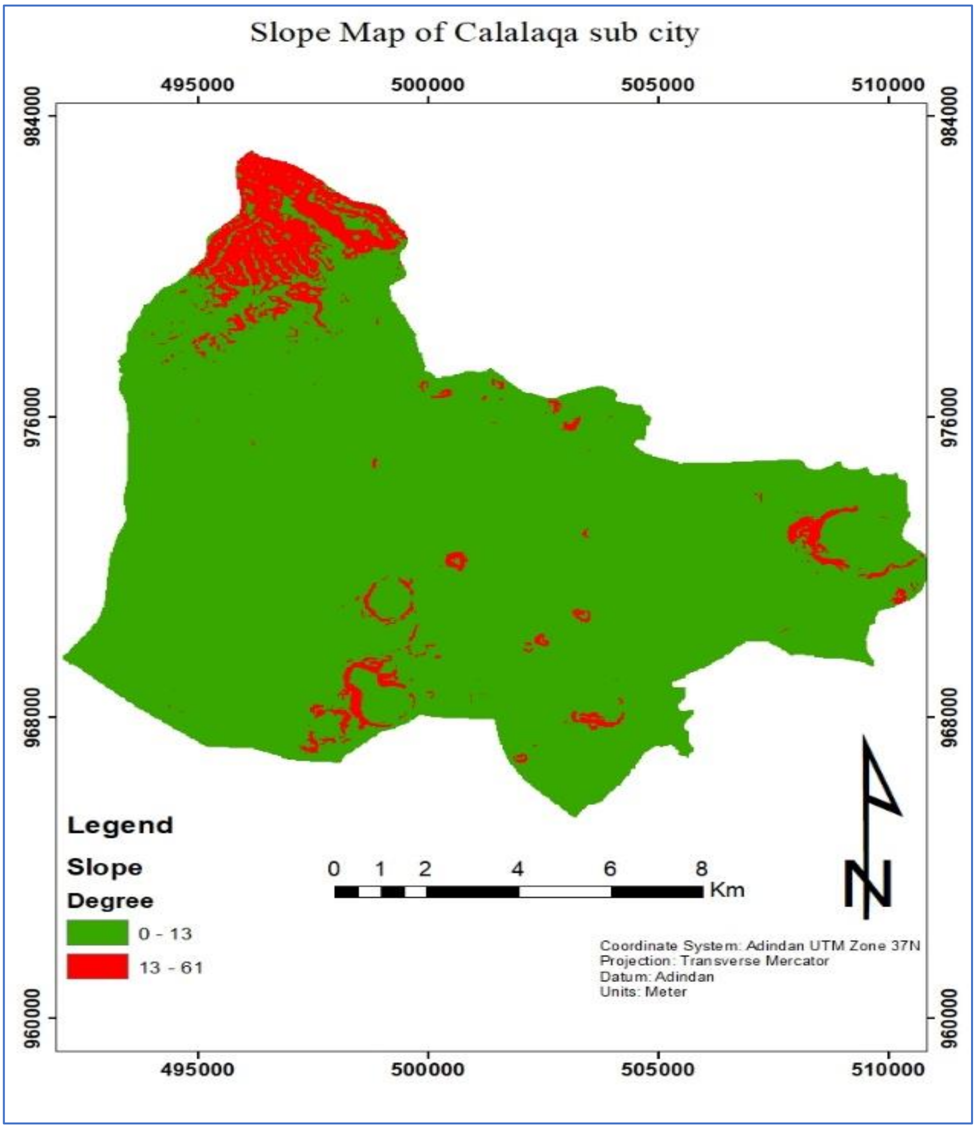

Figure 4.7. High and low Slope map of study area

(Source: Computed based on the data obtained from ASTER DEM)

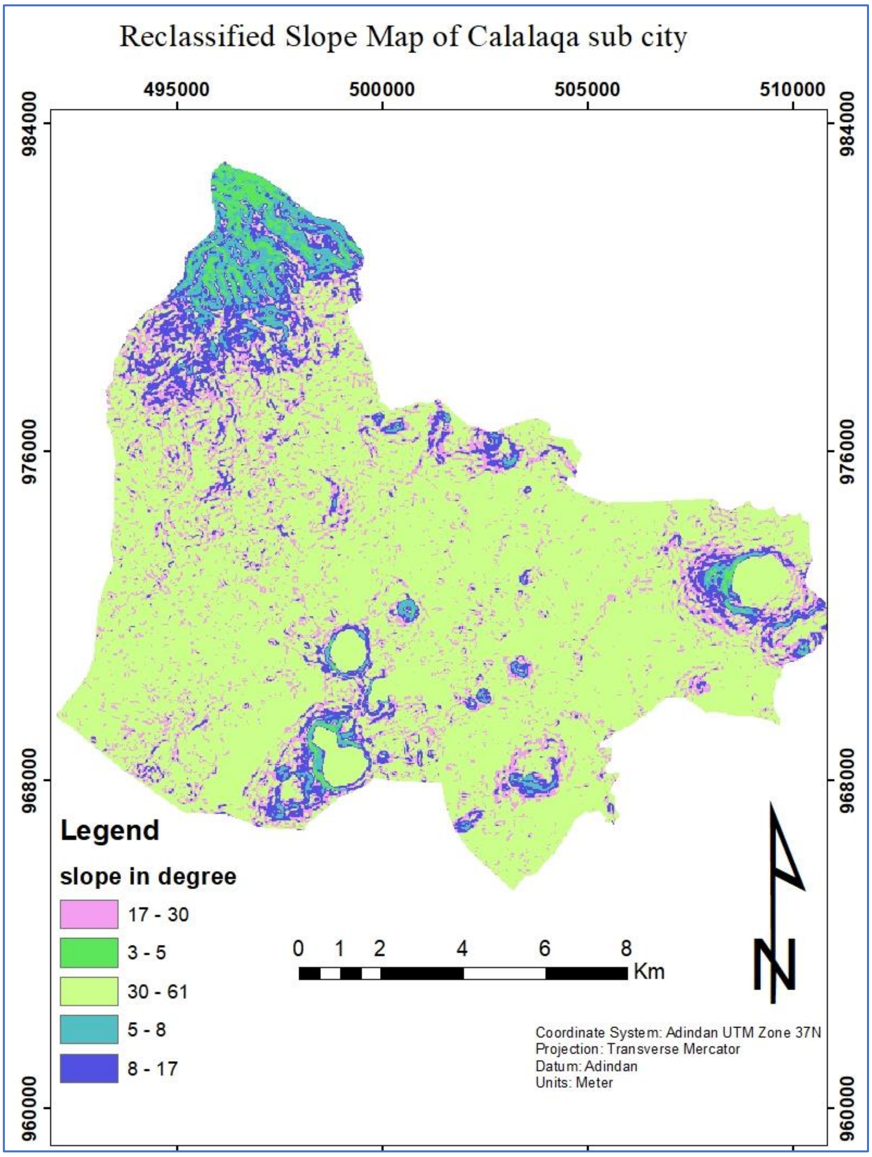

Figure 4.8. Reclassified Slope map of study area.

(Source: Computed based on the data obtained from ASTER DEM)

4.1.5. Land Use Land Cover

LULC circumstance of an area is also one of the major factors for the flooding vulnerability situation of the area. With this understanding in mind, the 2024 LULC analysis was carried out for study area. Table 4.2 indicates that study area covered 6046.16 hectares of land of which Farm Land covers the largest proportion of the total area of the Subcity.

Figure 4.9 below shows that the land use characteristics in the study area is mixed with water body, vegetation, Bare land, built up area and agricultural land but river and riverine are not given attention to protection in revers it covers small amount but its impacts are too high. Water body covers the smallest spatial area of the study area followed by the Open forest land. This gives us a clue about the flooding hazard vulnerability of the area in combination with other factors such as road paving and improper solid waste management.

Table 4.2. Area coverage and percentage of LULC class.

Class_Nme	Area	Percentage %
Bare land	1260.92	7.34
Farm land	6046.16	35.19
Open Forest	1065.67	6.20
Urban_Builtup	4690.73	27.30
Vegetation	3562.35	20.73
Water bodies	556.49	3.24
Total	17182.31	100

(Source: Computed based on the data obtained from USGS, LandSat,2024)

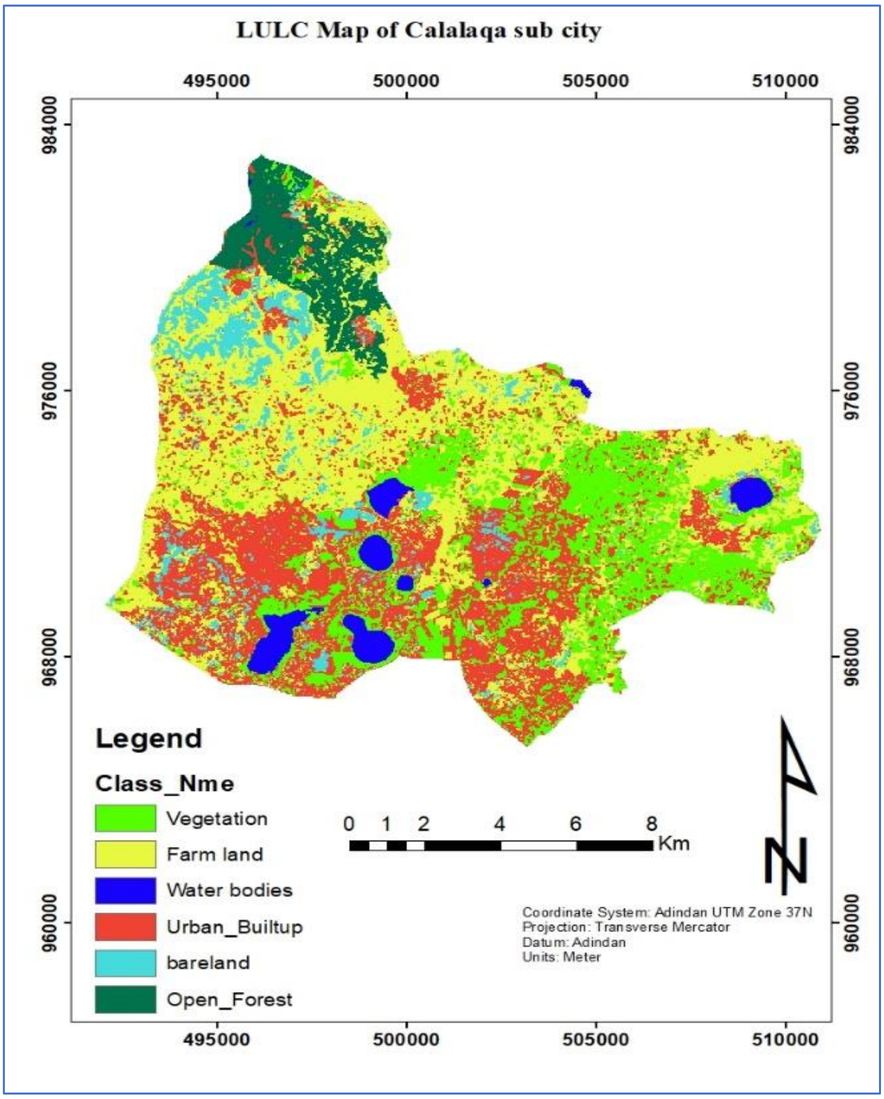

Figure 4.9. LULC map of study area ((Source: Computed based on the data obtained from Landsat 8 USGS,2024)

The study area of Land use and land cover highly covered by Farm land, second Built-up area. This shows due to high urbanization vegetation cover are changed in to buildings and industries as most of the time manufacture and industries built along the river side to the relations of waste disposal systems, this also affected the river, stream and the propulsion along the riverside released with other, but not given attention to the protections of flood and the protections of the stream and the rivers.

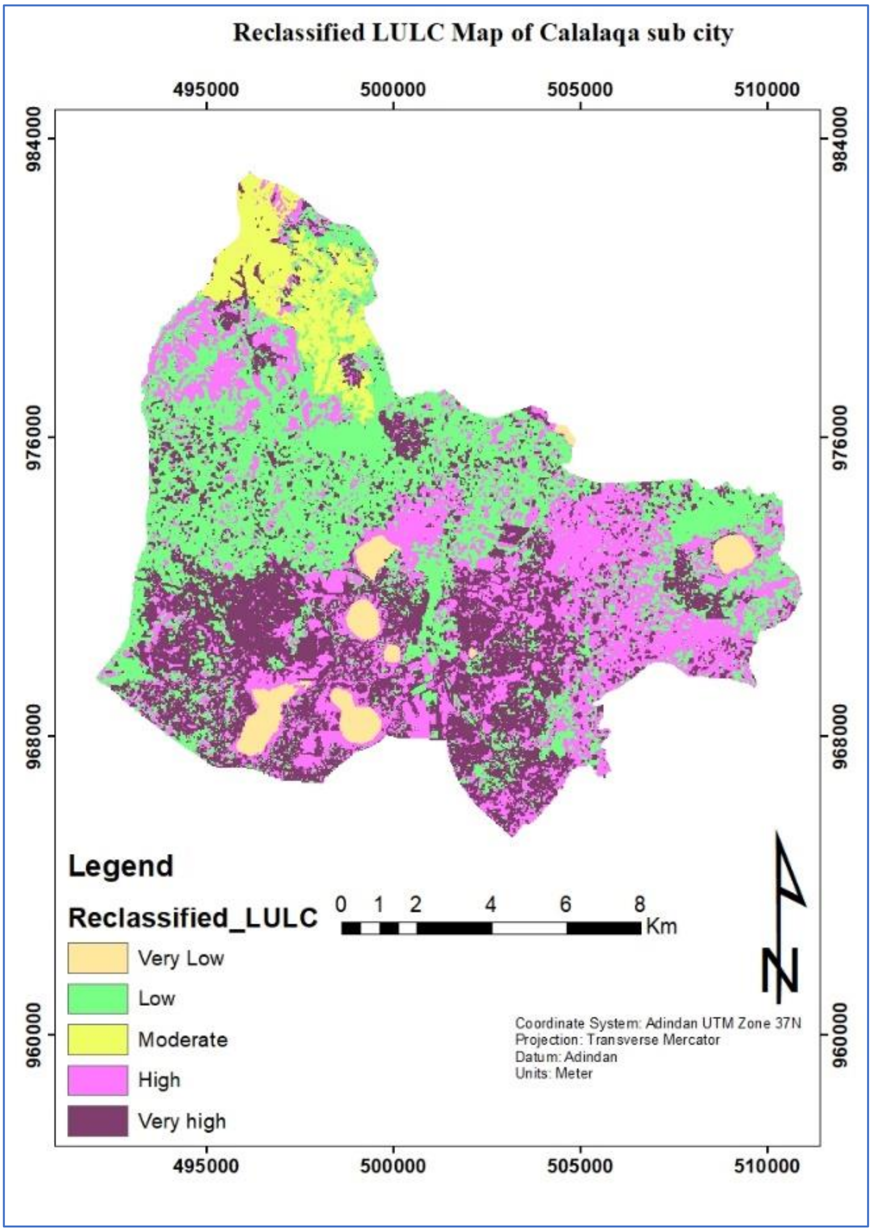

Figure 4.10. reclassified land cover map . (Source: Computed based on the data obtained from Landsat 8 USGS,2024)

Figures 4.6. above are the reclassified land cover map which is important because it reflects the current use of the land and gives an indication of the soil infiltration ability. A vegetation or forest cover, slows down and reduces the amount of runoff while urban land cover which is characterized by paved and impermeable surfaces absorbs no water and increase runoff and therefore increases the probability of flooding. From inspection of figure 4.10, it is noticed that majority of the study area has the Farm land and urban Built-up land cover. The urban land cover was assigned a very high rank as it is deemed the highest to cause flooding. This was followed by bare ground with a high rank. The forest and vegetation land covers were ranked moderate as they both slow down runoff and existing water bodies were ranked low.

4.1.6. Land Cover Classification Accuracy Assessment

The accuracy of the unsupervised classification is assessed by generating an error matrix. The error matrix generated is made up of values that are obtained by comparing the class assigned to a feature during the classification process to the actual value of the feature from a satellite image (google earth). To do this, random points are generated. At least Fifty (120) random points for each class were generated for the study area (figure 4.11). The error matrix table is then produced by comparing these two values to determine which features have been wrongly classified. Table 4.3 is the error matrix table resulting from the comparison.

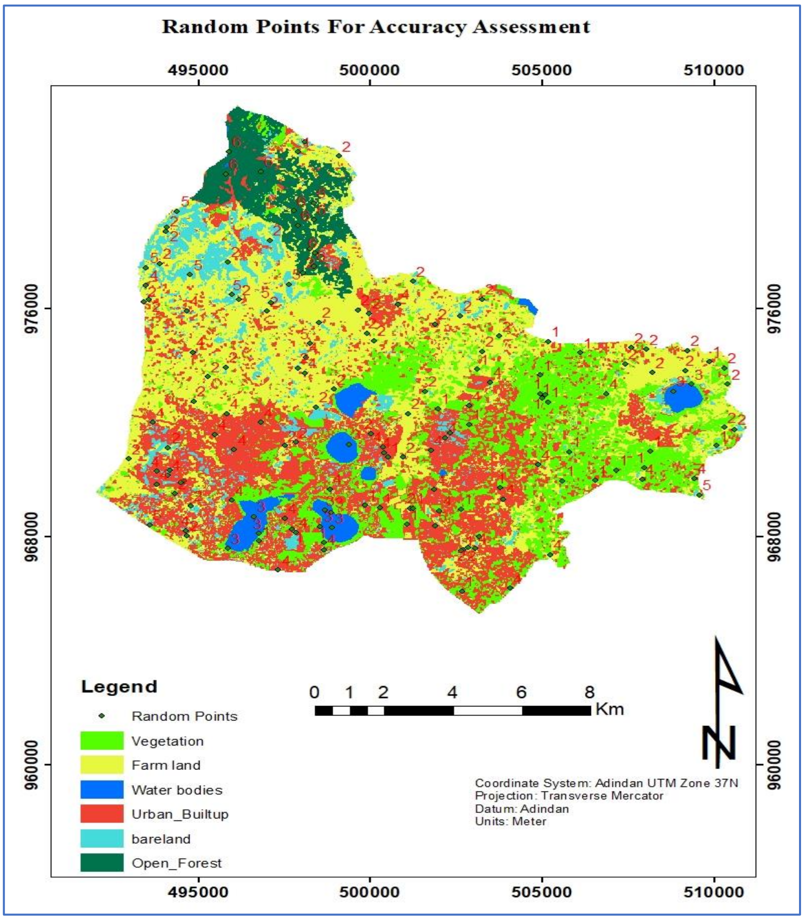

Figure.4.11. Accuracy Assessment and random points distributed on Classified Image.

(Source: Computed based on the data obtained from ASTER DEM)

Table 4.3. Accuracy Assessment and Error confusion of LULC

	Classified Data								
Class Value	Vege-tation	Farm land	Water body	Built-up	bare land	Open Forest	Total	User Accuracy	Kappa
Vegetation	29	1	0	0	0	1	31	0.94	0
Farm land	1	48	3	0	0	1	53	0.91	0
Water body	0	0	10	0	0	0	10	1.00	0
Built-up	1	0	1	39	0	0	41	0.95	0
Bare land	0	0	0	2	9	0	11	0.82	0
Open Forest	1	0	0	0	1	8	10	0.80	0
Total	32	49	14	41	10	10	156	0.00	0
P_Accuracy	0.91	0.98	0.71	0.95	0.90	0.80	0.00	0.92	0
Kappa	0	0	0	0	0	0	0	0	0.89

(Source: Computed based on the data obtained from USGS, LandSat,2024)

The overall accuracy is the percentage of random points that were 120 points were used in image hence the accuracy of the classification is 92%. Ǩ values greater than 80% is an indication of strong accuracy between the land cover classification map and the ground reference data. Since the Ǩ value for this error matrix is 89%, it can be assumed that the accuracy of the unsupervised classification is in strong agreement with the ground reference data (in this case a google earth satellite image).

4.1.7. Main River (proximity to river)

Since locations near rivers are always at danger of potentially hazardous flood effects, distance from the river is regarded as a crucial element in flood risk mapping. The buffer zone was created along both banks of the river at 1.5 km intervals in the current study using the Multiple Ring buffer. The buffer classes were ranked from 1 to 5 in order to produce a reclassified buffer map of the main River's lower course. Since these areas are vulnerable to flooding even during small- to medium-sized floods, the zone within 1.5 km of the river was given a score of 5, while the zone farther downstream, at a distance of 6km and above, was given a rank of 1.

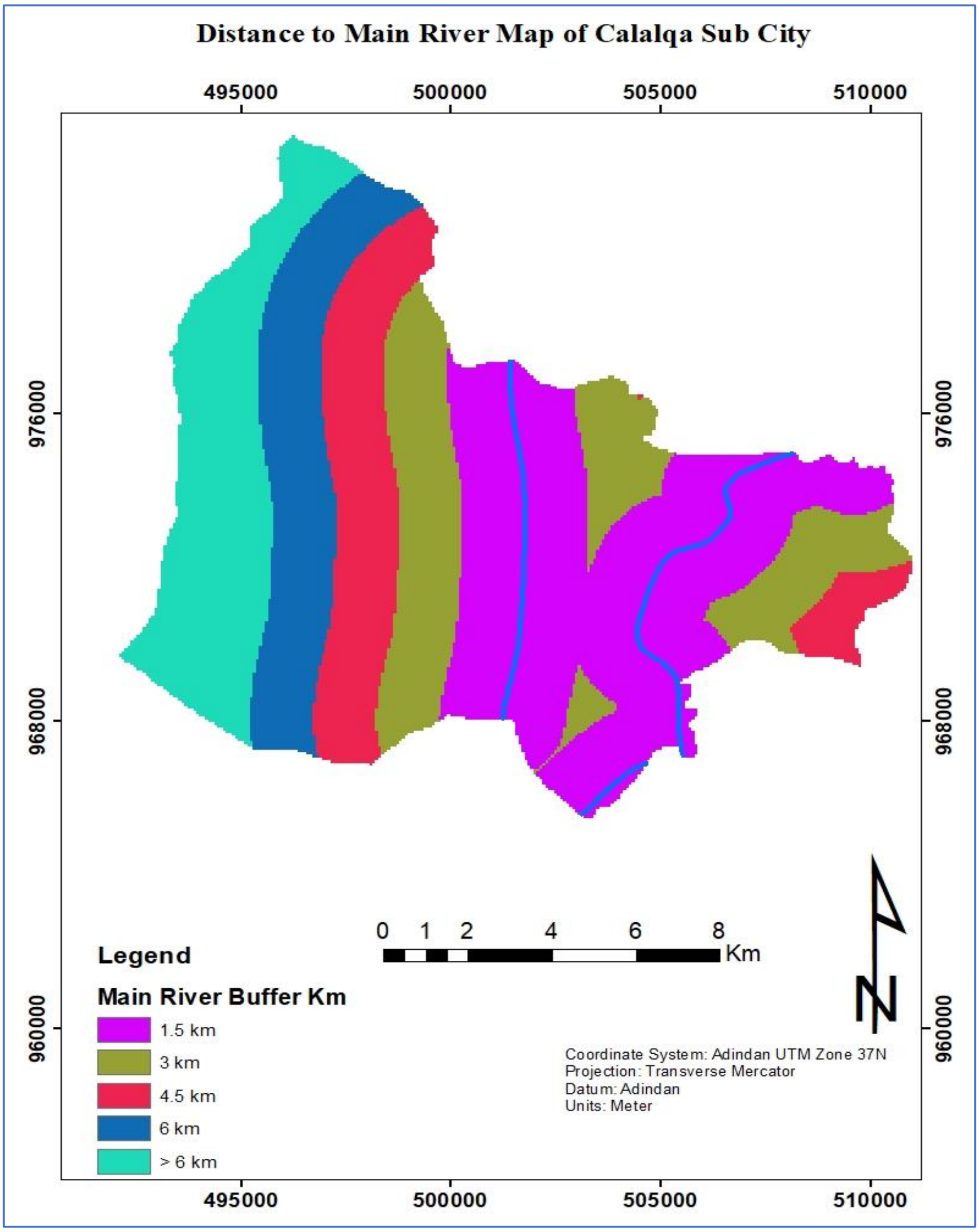

Figure 4.12. Main River Buffer (proximity) (Sources,Ethio,Gis)

4.1.8. Geology (Soil Types)

One of the characteristics of soil which has an influence over flooding is soil texture (types). The texture of the soil gives an indication of the infiltration capacity of the soil. Soils with porous texture such as sandy soils, absorbs water easily and creates less runoff whereas less porous soils such as clay, holds water for long periods. According to the soil classification the different soil types in figure 4.13 have high clay content with the exception of the impure sandstone which has relatively less clay content hence the reclassification of the study area into five ranks. Figure 4.14 reclassified soil ranked as Very low to very high.

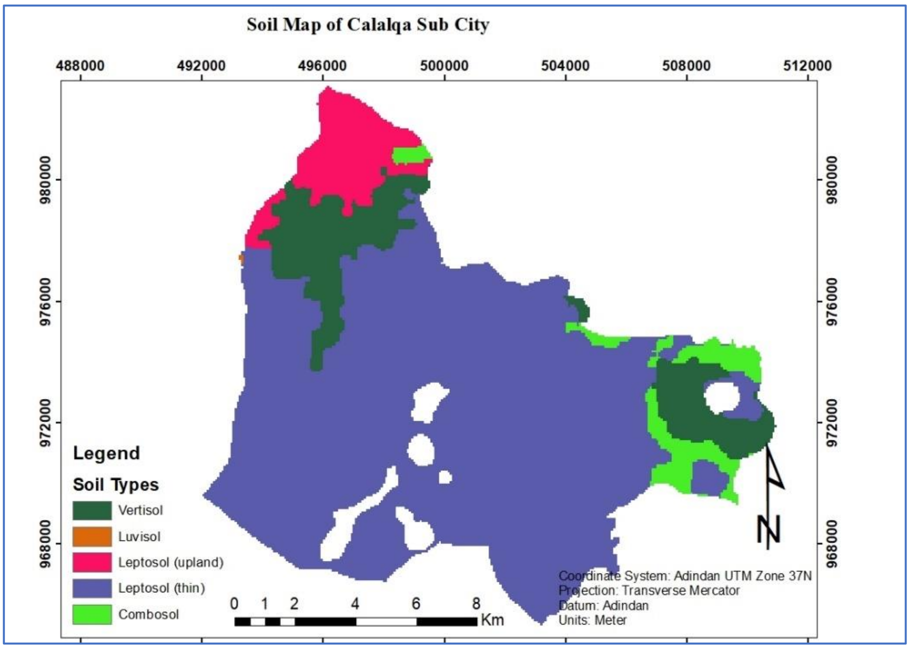

Figure 4.13: Soil map of Study area. (Sources FAO,1984)

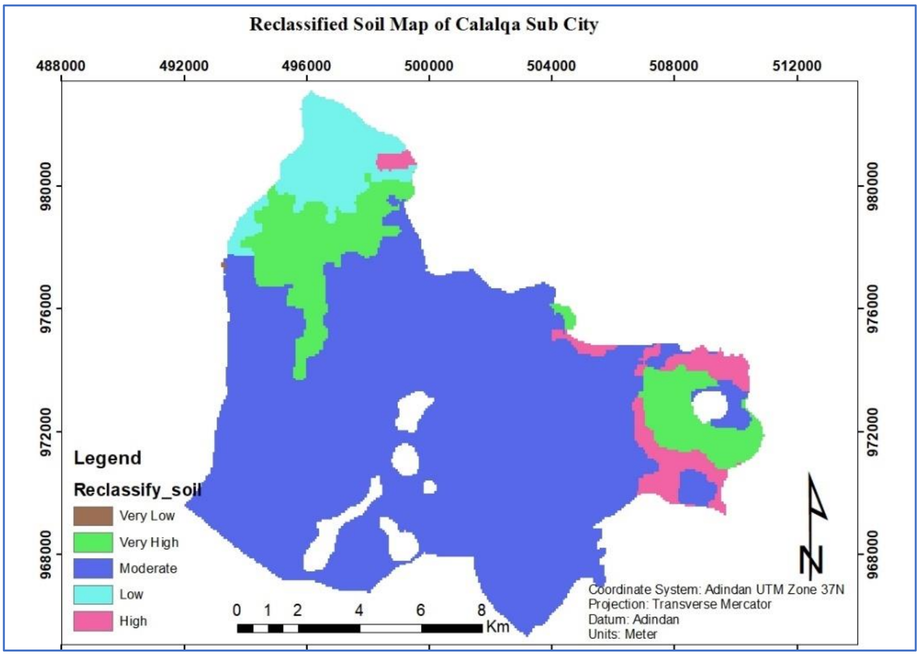

Figure 4.14: Reclassified geological map (Sources FAO,1984)

4.1.9. Flow Accumulation (Drainage network)

The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell. A flood, put simply, is the accumulation of water over normally dry land.

between 22866.82 and 24897.11 = High; and between 24897.11 and 28802.23 = very High rankings respectively.

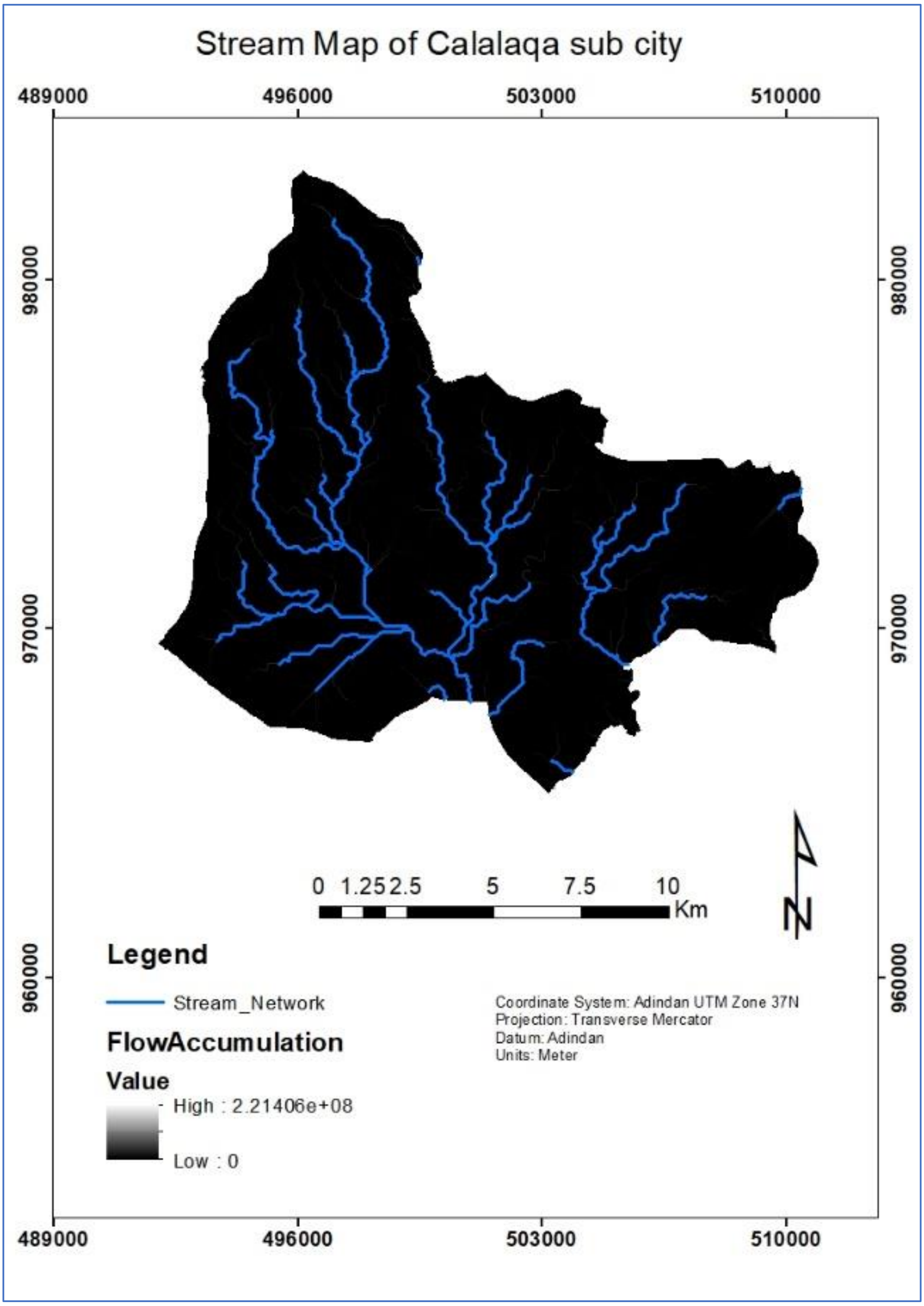

Figure 4.15: Flow accumulation of study area.

(Source: Computed based on the data obtained from ASTER DEM)

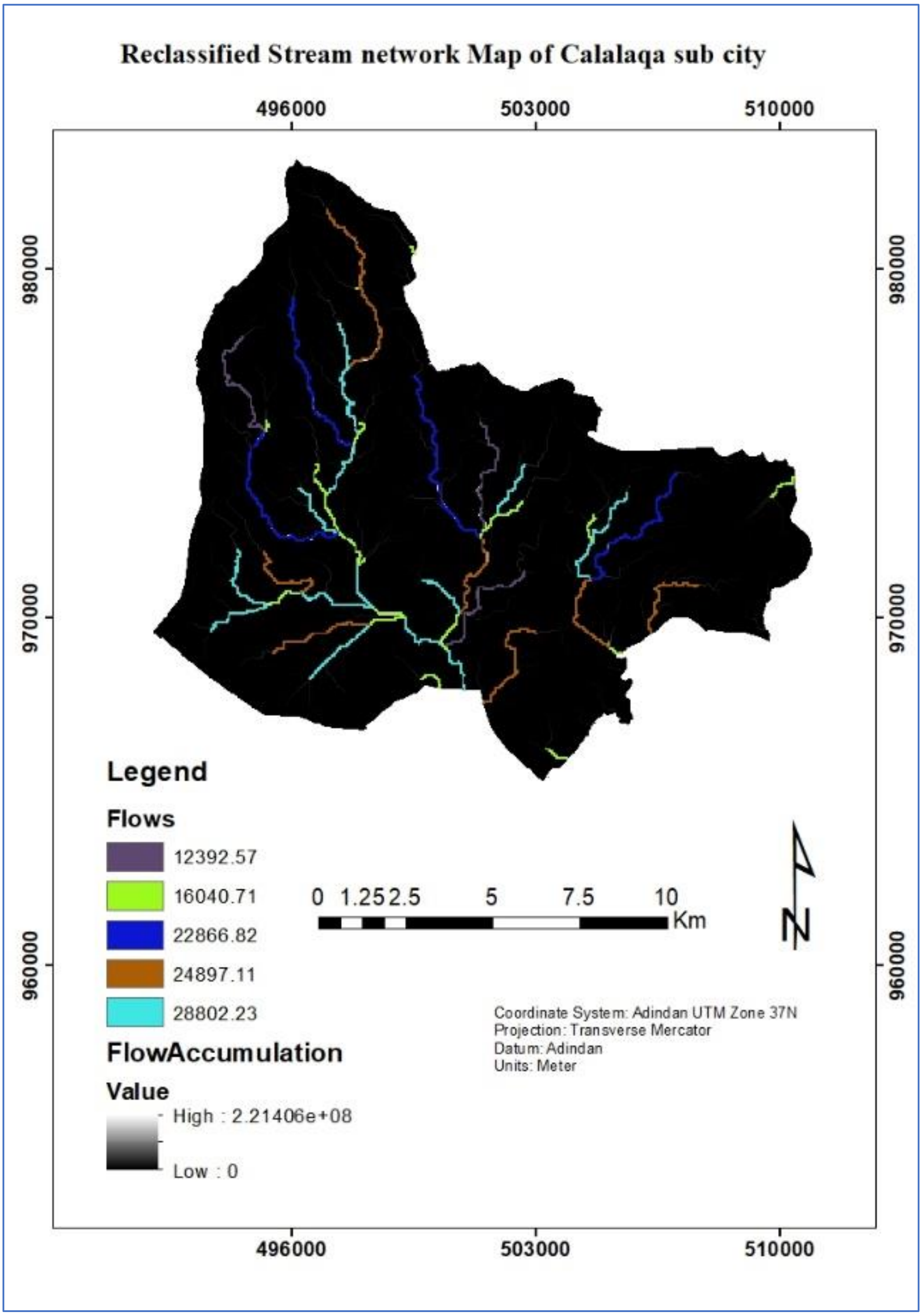

Figure 4.16: Reclassified stream network.

(Source: Computed based on the data obtained from ASTER DEM).

It's typically caused by the overflow of coastal or inland waters (like rivers and streams) or by an unusual accumulation of water from heavy or prolonged rains, storm surges, or sudden snowmelt.

Figure 4.15 below is the stream network extracted from the Aster DEM and Figure 4.16 is the reclassified stream network. The different colours represent the different flow accumulation. As stated before, flow accumulations between 0 and 12392.57 = very low; between 12392.57 and 16040.71= Low; between 16040.71 and 22866.82= moderate.

4.2. Weighed Overlay Results

Multi-criteria weighted-overlay analysis is the process of the allocating areas on the basis of a variety of attributes that the selected areas should possess. Although this is a common GIS operation, it is best performed in the raster space using a grid-based approach. Based on the stated criteria in previous section the weighted overlay analysis was done. while preparing hazard map the field investigations in the study area revealed that majority of the area lacked proper drainage systems and existing drainage systems are characterized by inadequately sized culverts which are often blocked by deposition of garbage and an accumulation of silt caused by years of neglect and lack of maintenance.

Investigations also revealed that due to increased residential, commercial, and infrastructure developments, there is an increase in impervious surfaces which results in an increase in storm water runoff. It was also observed that obstruction of flows by buildings across natural stream courses and inadequate capacities of culverts and stream channels also contributes to flooding.

The flood hazard map which resulted from the multi criteria analysis is shown in figure 4.17 below and table 4.4 indicates the percentage coverage of hazard zones. The resulting map suggests some level of flooding is experienced in all areas under the study area.

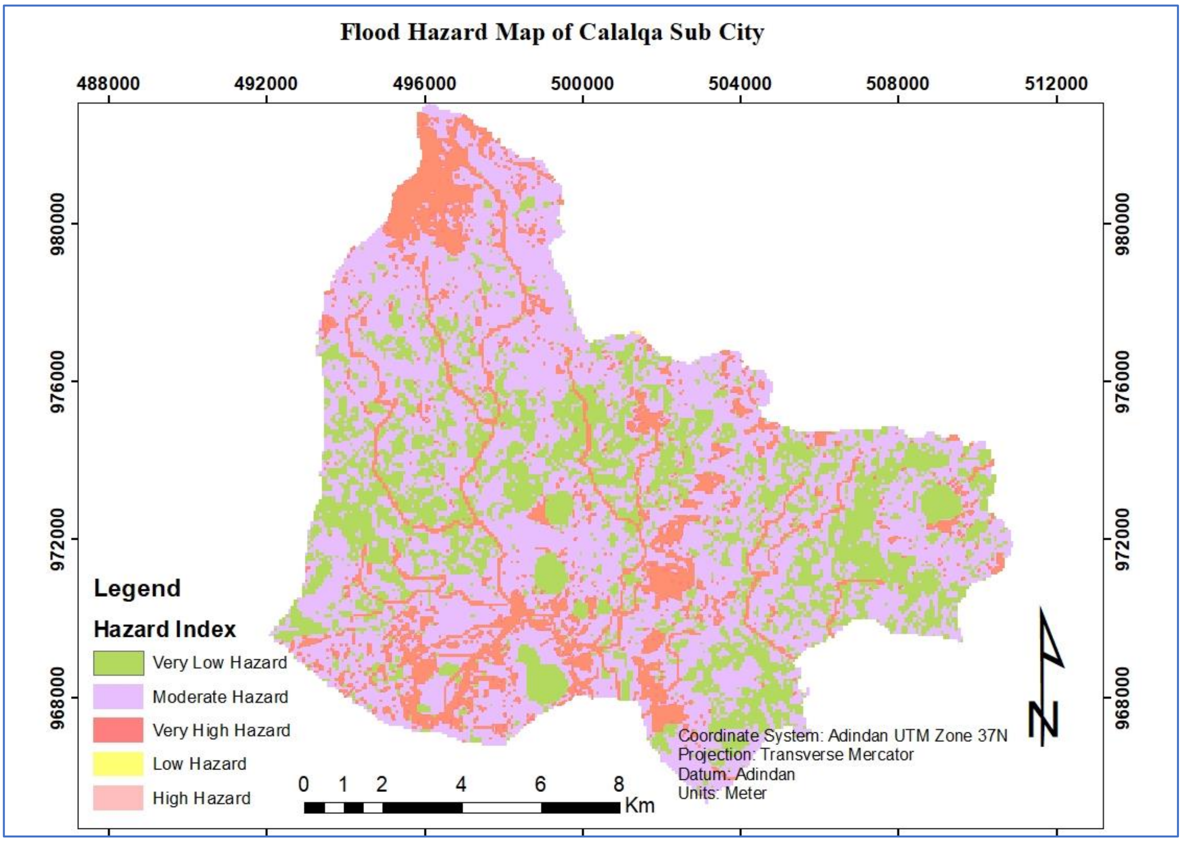

Figure 4.17: Flood Hazard Map

The area vulnerability to flooding was analysed by using GIS-based mapping technique (Figure 4.17). As shown in the map, the area covered by red coloured is found to bet very highly vulnerable. It occupied the largest part of the study area indicating the fact that most areas are very vulnerable. On the other hand, it is possible to conclude that the households residing in red-coloured areas are very highly prone to flooding. rose coloured areas are highly vulnerable; whereas the vulnerability of Violate areas is moderate. Only green coloured areas are found to be not vulnerable for flooding in the study area.

Table 4.4. hazard Zone area Coverage

Flood_Hazard_Index	Area in (Ha)	Percentage (%)
High Hazard	3940.443	22.922
Low Hazard	2271.735	13.215
Moderate Hazard	3812.590	22.179
Very High Hazard	3129.940	18.208
Very Low Hazard	4035.665	23.476
Total	17190.373	100

(Source: Computed based on the data obtained from USGS, LandSat,2024)

Comparing the weighted flood hazard map to the land cover and reclassified land cover maps, it is noticed that the areas in the flood hazard map experiencing very high and high levels of flooding falls within areas with the urban land cover. To ascertain whether the resulting map from the MCA process is a close representation of the flood prone areas in the study area.

4.3. Causes and impacts of flooding hazards in study area Community perception.

This sub-title has been addressed by using qualitative research approaches such as key informant interview, focus group discussion and observation. Interviews with persons having special practical information about flooding hazards in study area have been carried out. This focuses on organizing formal interview with the aim of facilitating open interaction between the researcher and key informants.

4.3.1. Perceived causes and effects of flooding

Respondents were asked to state the origins of flooding in their area. According to their response, they indicate that the main causes of flooding in the area were heavy rain (20%), Poor urban drainage system/ drainage line stuffed with garbage (15.5%) and Lack of drainage system (13.5%), Development of housing and blockage of the natural drainage or water way and Topographic Location of property account for same percentage (11.6%). unplanned human settlement, Lack of Vegetation and deforestation and lack of maintenance of protective construction/retaining were mentioned as second order causes of flooding in the area (see Table 4.5).

Table 4.5: Major cause and driving factors of the flood.

Major driving factors of the flood	Frequency	Percent age (%)
Lack of drainage system	13	13.7
Poor urban drainage system/ drainage line stuffed with garbage	15	15.8
unplanned human settlement	7	7.4
Lack of Vegetation and deforestation	10	10.5
Topographic Location of my property	11	11.6
Development of housing and blockage of the natural drainage or water way	11	11.6
lack of maintenance of protective construction/retaining structure.	9	9.5
Heavy Rain	19	20.5
Total	95	100.0

The most notable effects of flooding in the area were also stated. The leading effects were Physical Infrastructure Loss (Damage the Street, Drainage, Electric and Others) (18.9%), destroyed household equipment (9.5%), and health concerns (27.4%). While 23.2% of respondents with none effects. (Table 4.6).

Table 4.6: Effects of the flood in settlement responses of respondents

Effects of flood	Frequency	Percentage (%)
Physical Infrastructure Loss (Damage the Street, Drainage, Electric and Others)	18	18.9
Destroyed House	13	13.7
Destroyed house hold Equipment	9	9.5
Health Effects	26	27.4
Pet Animal Life Loss	7	7.4
None	22	23.2
Total	95	100.0

4.4. Measures taken by the community and the government in mitigating flooding hazards.

4.4.1. Preparedness and response Protection Measures

Respondents have a strong belief that residents should take measures to protect themselves or their property from flooding (40%). While 24.2 % of community strongly disagree that cannot protect themselves or their property from flooding. However, it is about half of the households that had a plan that has been implemented to prevent the household from flood before it happening, during the event and post.

Table 4.7. Preparedness of households against flooding

Level of Agreement	Frequency	Percentage %
Strongly agree	38	40.0
Agree	7	7.4
Neutral	15	15.8
Disagree	12	12.6
Strongly Disagree	23	24.2
Total	95	100.0

Regarding plan or strategy from their side that has been done to prevent the flood before happening, during and after It is only in a quarter of these households that the coping strategy was effective. A coping method most often employed by households when flood occurs stated by the respondents in order of magnitude were: filling sand in bags and placing around the edges of the premise (41.1%), diverging the water way to other parts (20%), evacuate from premises (31.6%), moving to higher ground (5.3%), and others (2.1%) (Table 4.8).

Table 4.8. Respondents response Coping method you usually use when flood occurs.

Coping Methods	Frequency	Percentage %
Moving to higher ground	5	5.3
Filling sand in bags and placing around the edges of our premises	39	41.1
Evacuate from the premises	30	31.6
Diverging the water way to other parts.	19	20.0
Others	2	2.1
Total	95	100.0

The householders place sand bags across doorways and cover all drainage holes and floor drains to stop back flow of flooding water as a mechanism for flood protection. Besides, during rainy season, the residents make a retaining wall-like structure with a hollow block to defend flooding hazard. Such walls are essential for holding soil and preventing erosion. They can also deter flood water by directing the water toward the street. That means according to the householders understanding retaining water can protect their property from flood damage.

Table 4.9. indicate that the Authorities undertake actions to prevent flooding 33.7% of Facilitating Peoples evacuation. Some of the respondents attested that authorities were willing to take necessary measures to reduce flood damages. Similarly, the support provided from government and non-government organization to prevent flood before, during and after happening was limited. The actions that government authorities usually take in combating the risks of flooding were: Early warning (10.5%), cleaning and maintaining drainage system (27.4%), and insurance compensation account for only (4.2%) (Table 4.9).

Table 4.9. Preparedness and response measures by GOs and NGOs.

Actions to prevent flooding	Frequency	Percentage %
Cleaning and maintaining drainage system/ditch	26	27.4
Facilitating People ‘s evacuation	32	33.7
Early warning the community	10	10.5
Insurance and compensation	4	4.2
Others	23	24.2
Total	95	100.0

4.5. Discussions

From the flood Hazard map, the whole study area can be considered as a flood plain as the terrain is fairly flat. The areas with moderate, high and very high floods are heavily populated urban areas where, in addition to residential properties, all the industries, markets and commercial activities are located. In the event of flooding, commercial activities grid to a halt and millions of dollars of property are lost. The conventional method of relocation of persons within flood plains cannot be applied here since it would imply the relocation of a population. Also, since the raining season is just four months out of twelve, relocation seems unrealistic. This suggests that other ways of combatting the perennial flooding are needed.
Comparing the weighted flood hazard map to the land cover and reclassified land cover maps, it is noticed that the areas in the flood hazard map experiencing very high and high levels of flooding falls within areas with the urban land cover.

To ascertain whether the resulting map from the MCA process is a close representation of the flood prone areas in the study area, satellite images of the study area were analysed. From the results of hazard map area coverage by low and very low hazard was 3.3% and 0.3% respectively. While the area coverage in percentage of 37.2% very high hazard area and 49.9% show High flood hazard area.
The result relates to the argument that flooding risk perception is connected with the person knowing that they reside in flood prone areas.
Warning systems are a way of getting information about threatening event of flooding, communicating that information to those who need it, and facilitating good decisions and timely response by people in danger. Thus, early warnings are key in stimulating instant response to flooding and develop an effective mitigation measure.
However, according to qualitative data result; this study came up with absence of strong early warning system from the government side and considered as a challenge that households residing in medium and high flood risk areas encounter. Respondents have a strong belief that residents should take measures to protect themselves or their property from flooding (40%). While 24.2 % of community strongly disagree that cannot protect themselves or their property from flooding.
coping method most often employed by households when flood occurs stated by the respondents in order of magnitude were show the high value of their own use filling sand in bags and placing around the edges of the premise which account for (41.1%) from total.

Some of the respondents attested that authorities were willing to take necessary measures to reduce flood damages. Similarly, the support provided from government and non-government organization to prevent flood before, during and after happening was limited.

The actions that government authorities usually take in combating the risks of flooding were: Early warning (10.5%), cleaning and maintaining drainage system (27.4%), and insurance compensation account for only (4.2%). Information and knowledge are precursors to flooding risk perception of households and the level of preparedness and protection measures against flooding taken by householders.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Flood risk mapping is an essential component for relevant land use planning in flood plain areas and it aids in the efforts of city planners and administrators to prioritize their mitigation or relief response. The basic notion of flood risk mapping undertaken in this thesis is to efficiently delineate flood prone areas and prepare hazard map. It is achieved through a multi criteria evaluation method within a GIS environment-based overlay analysis.

The multi-criteria analysis approach used in mapping flood hazard areas required the combination of the following identified decision criteria; elevation, slope, drainage, land cover, Normalized Difference index (NDVI), Normalized Difference Moisture Index (NDMI), soil geology, flow Accumulation (Drainage density) and Distance to Main river. Several GIS operations and image processing techniques were employed in the methodology. And the resulting map indicates that over 25 percent of the study area is likely to experience a high level of flood.

The effects of flood hazards on urban households residing along poor settlement area floods effects in the study area are one of the most dangerous, and frequent catastrophes assessing households residing along the stream, and river sides. Flood causes the disturbance of ecology and enormous impacts on environment, health risks, social disturbance, economy and financial disorder, loss of city infrastructure, and transportation systems, psychological frustration of the current and future risks.

The frequency of the events and the number of people affected including losses of home and the estimated damage, because they are the most flood prone areas, this mainly happened due to population growth, urbanization and rapid expansion of built up area in most part of the city and this has changed the built-up area.

The study aims to reduce the harmful effects of flooding on environment, social, human health and economic infrastructure by limiting the impact of a flood before, during and after a flood event activity that have undertaken by the population at risk, by policy makers administrative bodies and by emergency workers in order to reduce flood risks by the help of fields of engineering and urban planning.

5.2. Recommendations

The resulting map of MCA analysis can be used as a guide for decision makers and city planners for better land use planning and flood risk management while the radar analysis is best used for managing disaster and directing relief measures since it shows exactly where flooding had occurred.

The methodologies presented in the thesis are applicable to other flood prone regions. The accuracy and visualization of the MCA work presented can be further improved by using high resolution DEM data which will generate flood inundation map with high accuracy and extensive rainfall and ancillary data for accurate flood prediction analysis. Future work that can be carried out would be to examine different land cover categories that were flooded by overlaying the flood extent map derived from SAR with the land-use/cover classification from landsat-8 OLI data.

Recommendations for engaging the situation are as follows;

Engineering Solutions: In phase one of the disaster management cycle, two actions are considered; mitigation/prevention and preparedness. For mitigation/prevention, there is the need to plan, design and construct new drainage systems in the Bishoftu City area, to remove the hydraulic deficiencies of the existing drainage channels. An integrated drainage master plan incorporated existing built up areas, areas currently under development and future development areas should be drawn up. Also, drainage systems should be covered to prevent objects from choking them. With regards to preparedness, anticipated flooding events need to be appropriately estimated based on satellite imagery, updated rainfall intensity and duration data.

Land-use Controls: More open spaces should be included in design of new settlements to aid in the reduction of water runoff. Porous materials that are stable and strong, but that still permit water to drain through can be used in the construction of driveways, sidewalks, parking lots and pathways.

Town Planning: It is imperative that builders acquire building permits before buildings are erected. This will ensure that wetlands are not filled in and waterways and stream channels are not blocked.

Finally Based on the findings of this study, the following issues are recommended to minimize the vulnerability of households to flood hazards and resilience in study area.

- The Urban Land Administration Offices of Bishoftu City should control the improper settlement along the river side and map of the flooded areas can be created by the software which shows levels of flood hazard and prioritization measures for anti-flood.
- The Urban Land Administration Offices of Bishoftu City shall work on the fact that the river and river side offices must come up with a proposal to upgrade the infrastructure in the flooded area in terms of building of new barrier catchments, re capacitating of the

existing catchments, roads and the drainage by implementing plan with timelines to deliver on them to avoid the flood risk and give rapid response.

- Adopting an early warning system by using geographic information systems and remote sensing techniques in monitoring and managing urban land changes and its proper implementation. That has been proven to assist with the procedures to collect and analyse spatial data for hazard and risk assessment. Hence, Urban Land Administration Offices of Bishoftu and other concerned office and individuals shall take action.

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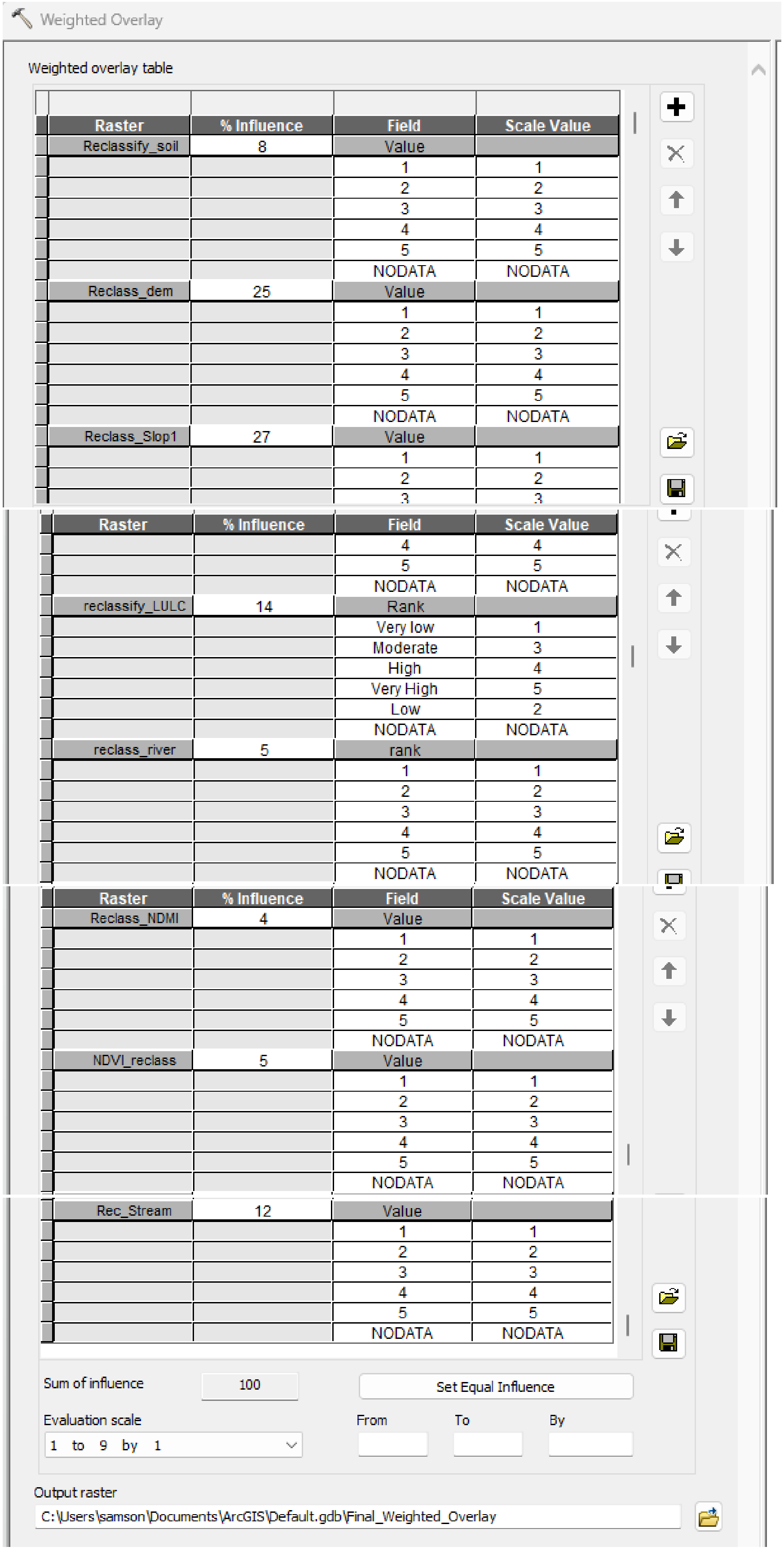
APPENDIX

Weighted overlay process


Weighted Overlay

Weighted overlay table

Raster	% Influence	Field	Scale Value
Reclassify_soil	8	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
Reclass_dem	25	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
Reclass_Slop1	27	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
reclassify_LULC	14	Rank	
		Very low	1
		Moderate	3
		High	4
		Very High	5
		Low	2
		NODATA	NODATA
reclass_river	5	rank	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
Reclass_NDMI	4	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
NDVI_reclass	5	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
Rec_Stream	12	Value	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA

Sum of influence 100

Set Equal Influence

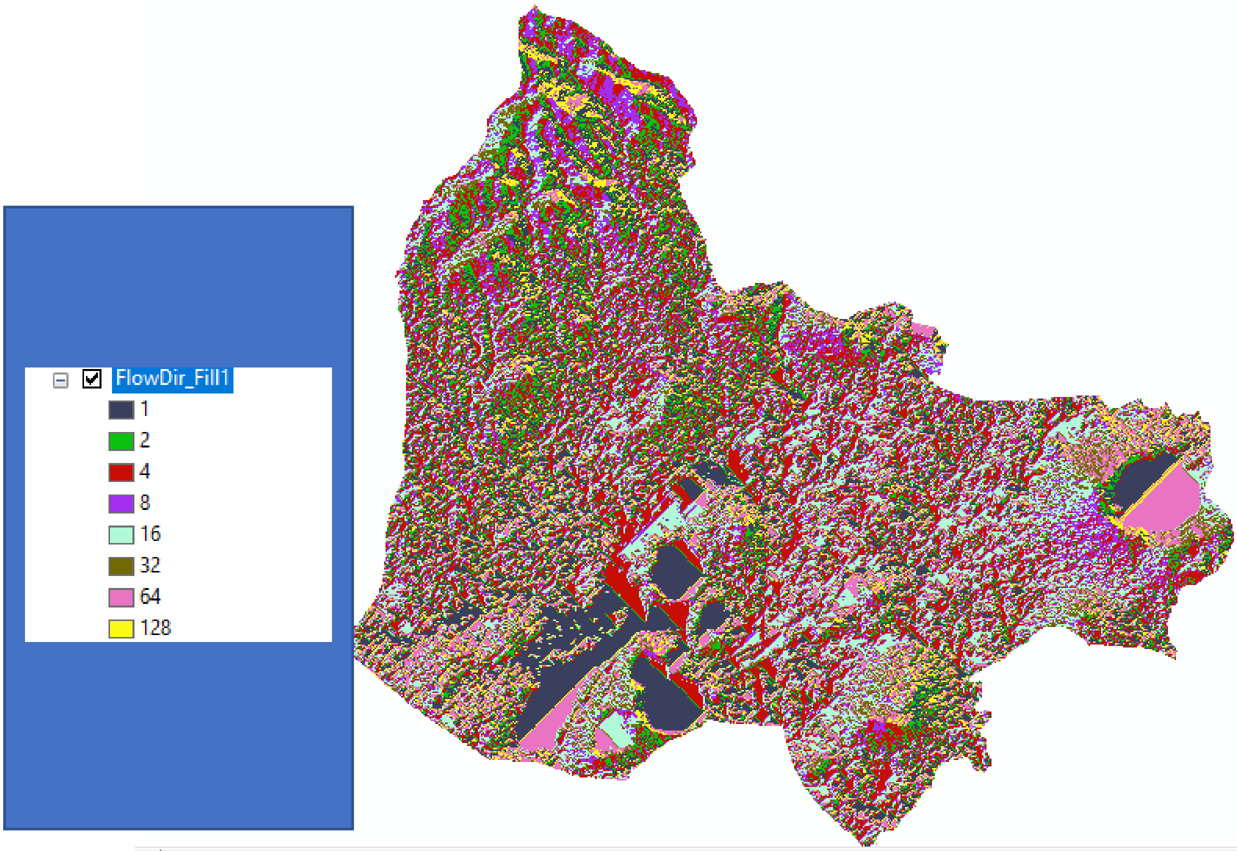
Evaluation scale 1 to 9 by 1

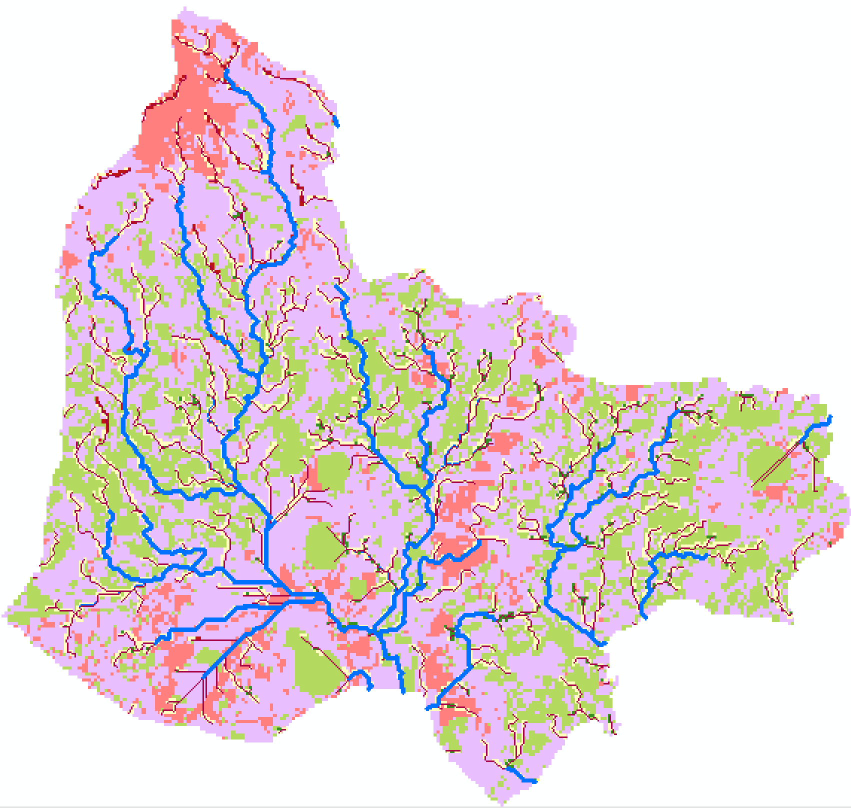
From To By

Output raster

C:\Users\samson\Documents\ArcGIS\Default.gdb\Final_Weighted_Overlay

Flow direction of the map





Main stream with hazard map

Respondents summary

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below 30	7	7.4	7.4	7.4
	30-49	23	24.2	24.2	31.6
	50-65	56	58.9	58.9	90.5
	65 and Above	9	9.5	9.5	100.0
	Total	95	100.0	100.0	

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	64	67.4	67.4	67.4
	Female	31	32.6	32.6	100.0
	Total	95	100.0	100.0	

Education Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Illitrate	23	24.2	24.2	24.2
	Read and Write	32	33.7	33.7	57.9
	Primary	12	12.6	12.6	70.5
	Secondary	11	11.6	11.6	82.1
	Diploma	11	11.6	11.6	93.7
	Degree and Above	6	6.3	6.3	100.0
	Total	95	100.0	100.0	

Questionnaire for Sample Households

<u>Dear respondents:</u> the purpose of this questionnaire is to gather information for conducting a study on perception of and response to flooding in Bishoftu calalaqa sub city.

The information obtained through this questionnaire will only be used for the research purpose. The quality of this study is highly depending on the information provided by you. Whatever information you provide me will be kept strictly confidential. You do not have to write your names. Thus, you are kindly requested to fill in the questionnaire according to the instructions provided. Thank you in advance for your kind cooperation!!

<u>General direction:</u> Please read each of the given items carefully and indicate your choice for items with options and circle your response on the provided items.

<u>PART 1.</u> Respondents Profiles

1. Sex: A. Male B. Female

2. Age: A. below 30 B. 30 - 49 C. 50-64 D. 65 and above
3. Educational status: A. Illiterate B. Read & Write C. Primary (1-8) D. Secondary (9-12) E. Diploma F. Degree & Above
4. Occupation: A. Farmer B. Daily laborers C. Merchant D. Self-employed E. Unemployed F. Civil servant G. Others
5. Number of individuals living in the household _____________
6. How long have you lived at or occupied the property? A. > 2year B. 2-5 years. C. 5-10 years D. 10-20 years E. <20 years
7. Please indicate the type of property? A. Residential house B. Mixed use (Residence + Commerce) C. Commercial D. School E. Other__________________________

PART 2. Questions Related to Household Level of Preparedness and Protection Measures

Against Flooding.

1. Should residents take measures to protect themselves or their property from flooding? *[A]* Strongly agree *[B]* Agree *[C]* Neutral *[D]* Disagree *[E]* strongly disagree
2. Is there any type of plan or strategy from your side that has been done to prevent the flood before happening, during and after? *[A]*. Yes *[B]*. No
3. In your opinion, is your coping strategy effective? What coping method you usually use when flood occurs? (NB: you can choose more than one).

   [A] Moving to higher ground *[B]* Filling sand in bags and placing around the edges of our premises *[C]* Evacuate from the premises *[D]* Diverging the water way to other parts. *[E]* Others______________________

PART 3. Questions Related to The Perception of Flood Causes & Effects

The way Household heads perceive the causes that generated amplified floods depend on their information, experience and knowledge level. Please indicate the level of agreement to the following items.

1. In your opinion, what are the major driving factors of the flood in your area? (NB: you can choose more than one)

   [A] Lack of drainage system *[B]* Poor urban drainage system/ drainage line stuffed with garbage *[C]* unplanned human settlement. *[D]* Lack of Vegetation and deforestation *[E]* Topographic Location of my property. *[F]* Development of housing and blockage of the natural drainage or water way [G] lack of maintenance of

protective construction/retaining structure. *[H]* heavy rain [I] Others_______________________

2. Can you Elaborate or mention the effects the flood has on you and others? (NB: you can choose more than one)

   [A]. Physical Infrastructure Loss (Damage the Street, Drainage, Electric and Others)

   [B] Destroyed My House [C] Destroyed house hold Equipment 's [D] Human Life Loss

   [E] Pet Animal Life Loss *[F]* Health Effects *[H]* None *[G]* Others_________________

<u>PART 4</u>. Questions Related to Confidence in Officials and Institutions

1. How would you assess the level of flood forecasting and flood warning by authorities? *[A]* Very High *[B]* High *[C]* Moderate *[D]* Low *[E]* Very low
2. To what degree do you trust the responsible authorities for your protection against flood? *[A]* Very High *[B]* High *[C]* Average *[D]* Low *[E]* Very low
3. Do authorities undertake actions to prevent flooding? *[A]* Yes *[B]* No; If yes, please indicate actions that were taken?

   [A] Cleaning and maintaining drainage system/ditch ***[B]*** Facilitating People 's evacuation [C] Early warning the community [D] Insurance and compensation

<u>PART 5</u>: KEY INFORMANT INTERVIEW GUIDE

Sex_______________ Age___________ Office: ____________________________

Responsibility: ____________________________Phone number: _______________

1. Do you think that flooding is a problem in Bishoftu calalaqa sub city?

   If yes 'please describe in detail
2. Please mention hotspot areas for flooding in your Sub city?
3. What do you think are the major causes of urban flooding in calalaqa sub city?
4. Is there any specific place that is said to be vulnerable for flooding?

   If yes please describe in detail
5. Please mention areas of support/ intervention by the government (before, during and after flooding) against flooding hazards in the sub city
6. What do you recommend to minimize the flooding hazards in calalaqa sub city?

   Please mention some comment and suggestion regarding flood resilience in the city
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Thank you very much for your time & professional support.