A Geospatial Technology Based Study on Flood Risk Assessment: A case of Akaki Kality Sub City, Addis Abeba, Ethiopia

By: Desybel Minwuylet Desta

A Thesis Submitted to

The department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Geoinformatics Engineering

Office of Graduate Studies
Adama Science and Technology University

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Advisor

Roba Gemechu (PhD)

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DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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indirectly made it possible for me to complete this thesis by any means of support.

LIST OF ACRONYMS

AACFEPRA	Addis Ababa City Fire Emergency Prevention and Rescue Agency
AHP	Analytical Hierarchy Process
DEM	Digital Elevation Model
DPPA	Disaster Preparedness and Prevention Agency
EC	European Commission
EGIA	Ethiopian Geospatial Information Agency
ERDAS	Earth Resources Data Analysis System
ETM	Enhanced Thematic Mapper
FAO	Food and Agricultural Organization
GCP	Ground Control Point
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
IDW	Inverse Distance Weighing
LULC	Land Use and Land Cover
LULCC	Land Use and Land Cover Change
KRCS	Kenya Red Cross Society
MCE	Multi Criteria Evaluation
MLC	Maximum Likelihood Classifier
NMA	National Meteorological Agency
OLI	Operational Land Imager
RCMRD	Regional Center for Mapping of Resources for Development
SRTM	Shuttle Radar Topography Mission
SPOT	Satellite Pour l'Observation de la Terre
TM	Thematic Mapper
PWC	Pair Wise Comparison
UNCHS	United Nation Center on Human Settlement
UNOCHA	United Nation Office for the Coordination of Humanitarian Affairs

USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGS	World Geographic System
WHO	World Health Organization
WLC	Weighted Linear Combination

ABSTRACT

Floods are one of the most common natural disaster in the world and causes of lives, livelihood and property destruction. Akaki Kality sub city was suffering from rainy season flood owing to several factors solid waste management generated from household and institution, increase population size (people dwelling near to stream). Accordingly, this leads to increase the occurrence of flood which creates socio- economic crises in the sub city. The objective of this study is to asses flood risk in Akaki Kality Sub-city using the application of geospatial technology. Flood risk assessment was done using flood vulnerability factors such as, drainage density, slope, elevation, rainfall, soil type and land use were rated and combined to delineate flood risk zones using a multi-criteria evaluation technique in a GIS environment. Therefore, the weight of each flood vulnerability factor was computed by pair wise comparison for a final weighted overlay analysis of all factors to delineate the flood risk map. Landsat image for 2009 and 2019 were used to classify the area in to cultivated land, forestland, grassland, settlement and wetland. The mapped data from satellite image of 2009 indicated that cultivated land covered for 5822.4ha, forestland covered for 1341ha, grassland covered for 456.5ha, settlement covered for 2282.8ha and wetland covered for 2442.7 ha from the total area of 12345.4 hectare covered. In 2019 there was cultivated land covered for 4364.4ha forestland, covered for 363.3ha, grassland covered for 290.1ha, settlement covered for 3197.9ha and wetland covered for 4129.7ha from the total area of 12345.4 hectare covered. The cultivated land decreased by 1458ha (25.0%) and forestland decreased by 977.7ha (72.9%). During this period grassland also decreased by 166.4 ha (36.45%). But, settlement and wetland were increased by 915.1ha and 1687ha which represents 40.1% and 69.1% rise respectively. Moreover, these changes alter surface runoff and affect soil infiltration capacities, which increase the occurrence flood in the study area. Finally, this flood risk map indicated that 30.2ha (0.2%), 1068.32ha (8.7%), 9057.24ha (73.4%) and 2189.64ha (17.7%) subjected to low, moderate, high and very high flood risk map respectively. Furthermore, proper land use management and afforestation, is significant to reduce the adverse effects of flooding particularly in the low-lying flood prone areas.

Keywords*:* *Flood, Geospatial Technology, MCE, Risk*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of Study

A Floods stand out to be the most frequent and devastating natural disaster around the world (Berz *et al*., 2001), affecting an average of 99 million people per year between 2000 and 2008 (WHO, 2010). According to (Jonkman, S.N., 2005), floods alone killed 100,000 persons and affected 1.4 billion people in the last decade of the 20th century. Floods are caused by natural events, by human activities, or by combinations of both and have the potential to injure fatally, displace a large number of people and cause damage to the environment (Balabanova, S. and Vassilev, V. 2010). There are two main types of floods namely: flash floods and river floods, some of the causes of floods include anthropogenic activities through human interruptions in the natural processes occurring due to increased settlement areas, population growth and economic assets in the lowlands and coastal plains prone to flooding (Balabanova, S. and Vassilev, V. 2010). This leads to changes in the drainage systems (EC, 2007). Several studies (Milly et al., 2002; Bronstert, A. 2003; Christensen, H.J. and Christensen, B.O.2003) indicate that land use changes could be behind the recent frequent and erratic floods. Another, over past decades high deaths recorded in Africa due to flooding as a result of population settlement patterns than a consequence of climate change. The reported show that, floods displaced 2.5 million people in Africa in 2009 and more than a million in 2007.

Topographically, Ethiopia is both a highland/mountainous and lowland country. It is evident that, the problem of river and rainy flooding in Ethiopia is getting more and more acute due to human intervention in the fragile highland areas at an ever increasing scale. According to United Nation Office for the Coordination of Humanitarian Affairs (UNOCHA, 2006), across Ethiopia, the number of people affected by the floods of 2006 was 357,000 including 136,528 forced to abandon their homes.

The currently, case study mainly in the Southern and South Eastern parts of the sub-city due to the gentle slope (there is no variation topography) characteristics of the relief in these parts. This the result of past recorded on flooding in Addis Ababa indicates, it was increasing from time to time. Moreover, there was wide evidence that the flooding in Addis had been continue to increase to the end of this century due to climate change (Weets, G. 2011 and Feyissa et al.

2018) and poor urban storm water management in Addis Ababa. Flooding is common in Kirkos, parts of Bole and Akaki, at a time of heavy rain. The topographic nature of the Southern and South Western were gentle, and the heavy rain drops from mountains flow to the Southern direction, makes the Akaki-Kality area to be more vulnerable to flooding. Similarly, another a recent study conducted by the Addis Ababa City Fire, Emergency Prevention and Rescue Agency (AACFEPRA, 2018); disclosed that 121,000 houses in Addis, including 1,000 government and private institutions are in locations vulnerable to flood risk. The agency study which took six months to complete identified 143 areas as having a high risk of flooding. A majority of the risky places are in Gullele, Nifas Silk and Akaki Kality Sub cities where houses are constructed near rivers and drainage sites. The Agency reported Addis Ababa Rivers and riversides face problems which include: badly polluted segments through direct discharge of domestic waste generated mainly from households and institutions; river bank erosion; and inaccessible rivers and riversides. All of these flooding events attributed to different land use change activities and absence of watershed management practices on the surrounding areas of Akaki Kality sub city. Due to this the issue of flood continues to be growing concern the Akaki Kality sub city especially people residing along river course and the flood flows to steeps area (Entoto hills) gentle area. Therefore, due to in this case the sub city was more flood vulnerable and motivate to do this specific thematic area. Reducing risks following flooding is largely dependent on knowledge available on floods and understanding regarding the nature of the physical space with the likelihood of being affected during floods events. Therefore, using modern techniques are necessary for use if appropriate measures to help the government, planning agencies and rescue institutions in establishing flood vulnerable areas and in mitigating against floods are to be put in place. However, this research was focused on geospatial technology-based flood risk Akaki Kality sub-city. Therefore, in order to delineate flood risk Akaki Kality sub-city; Multi Criteria Evaluation (MCE) method was evaluating the weight of flood risk areas. Therefore, this research was become just as important benchmark for planners and researchers regarding spatial planning in the study area. In addition, the results can provide significance input for sustainable land use plans and strategies for mitigating flood risk.

1.2. Statement of the Problem

An increase in the size of human population and consequent changes in settlement patterns has led to changes in LULC to address the needs of the land users in Kilifi County (Okoth, D. 2010). LULCC leads to alteration of natural drainage systems, impact on surface runoff and affects infiltration capacities, these are factors which contribute to flooding (Haber, J. 2016). In the same way, Ethiopia's topographic characteristic has made the country vulnerable to flood and resulting devastation (Enyew, B. and Steeneveld, G. 2014). In recent years, Addis Abeba has been increasingly affected by flooding due to its vulnerability to rainfall .In Ethiopia context Addis Abeba City is suffering from rainy season(June to September) flooding owing to several factors such as solid waste management generated mainly from households and institutions, increasing population size(people dwelling around the stream), many slum areas are highly populated, roads and lack of maintenance of ditch for long period of time disposing garden waste this leads to the mismatch of the volume of run off with the volume of drainage capacity a recent studied conducted by the Addis Ababa City Fire, Emergency Prevention and Rescue Agency(AACFEPRA, 2018). A majority of the risk place in Gullele, Nifas Silk and Akaki Kality Sub-cities where house are constructed near rivers and drainage sites. According to the agency annual reported, 53 flood vulnerable areas 83 people killed in the City from flood. Particularly at present, flooding is increasing and causing great loss of human lives and property. Another, the topography nature of the Southern and South Western are gentle and the heavy rain drops from mountains flow to the Southern direction, makes the Akaki Kality sub-city area to be more vulnerable to flooding. The vulnerability to flooding is more aggravated due to poor drainage system, rapid hose development along river banks and using inappropriate construction materials (Feyissa et al,.2018). Therefore, this leads to damage of private property, injury personal causative factors that occurred in the past flood risk. According to (Feyissa et al,.2018), stated that, 15% of total population is death occurred, 13% of total population highly injured, 55% private property damaged and 17% of it is displaced from their livings. Presently in the existing situation like this, it is important to consider major factors that contributed most in the past flood hazard. Moreover, the researchers were studied flood in the case study area, the severity degree of risk was increasing from time to time but, the response rate is still low even not anticipated at risk because of this, previous studies don’t used geospatial technologies.

1.3. Objective of the Study

1.3.1. General Objective

The general objective this study is to conduct flood risk assessment in Akaki Kality Sub-city using the application of geospatial technologies.

1.3.2. Specific Objective

The specific objective the study aimed to:

- ✓ Analyze the extent of landuse/land cover changes occurring in the study area,
- ✓ Identify flood vulnerability factors for in the study area,
- ✓ Delineate flood risk map of the study area using Geospatial Technologies

1.4 Research Questions

This research intended to answer the following basic questions which are derivatives of the above mentioned specific objectives:

- ✓ What is the rate of land cover and land use change in Akaki Kality Sub-city?
- ✓ What are the factors for flood vulnerability in study area?
- ✓ How to generate flood risk map in the case study area?

1.5. Significance of the Study

Flood risk maps are important in planning for mitigation measures against flood events. To develop a prevention and mitigation plan, assessment of floods requires information on the areas at risk of flooding. Mapping of flood risk areas is the first step towards identifying areas that are highly vulnerable. In general; the case study area different concerned bodies' beneficiaries including local community (people); governmental and researchers.

They can also used in:
People: enable to protect some property and infrastructure before flood hazard.
governmental organizations: identify flooded areas from extracted levels of delineated flood risk map which prioritizing flood zones.
Researchers: can use this output as a base line information.

1.6. Scope of the Study

This study was conducted on Akaki Kality Sub-city with an area of 12345.4 hectares and generated extent land use/land cover maps from remotely sensed satellite images which were used for identifying the extent change of LULC 2009 and 2019. This research has focus on identifying flood vulnerable areas based on the selected criteria's and delineate flood risk map using geospatial technologies.

1.7. Limitation of the Study

The limitation of the study was lack of orthophoto data for 2009 and 2019 land use/land cover classification. Due to this limitation Landsat 7 ETM+ for 2009 and Landsat 8 OLI 2019 was used. Therefore, the analysis of Landsat image for 2009 and 2019 during land use/land cover classification was difficult to differentiated each LULC classes.

1.8. Common Terminologies

Geospatial technology is a multidisciplinary field that includes disciplines such as surveying, photogrammetry, remote sensing, mapping, Geographic Information Systems (GIS), geodesy and Global Navigation Satellite System (GNSS).

Flood is a natural phenomenon that results to the temporary submerging of a piece of land with water that does not occur under normal condition.

Flood Risk is a summation of the likelihood to occur of a flood, the anticipated impacts on human wellbeing, the biosphere, human culture and economic impacts related to floods.

Flood Risk Management refers to an all-inclusive process that incorporates a continuous process of analysis and assessment by an individual, a community or an agency to reduce the risks associated to floods.

Land cover is the physical state of the land surface such as cropland, forests, and wetlands, buildings, pavements, soil type, biodiversity, surface water and groundwater.

Land use is the way in which human beings exploit the land and its resources including agriculture, urban development, grazing, logging and mining.

Vulnerability is the ability of an individual or a group of individuals to anticipate, withstand or resist or rise up from the effects or consequences related to a hazard like a flood.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

This chapter presents reviews the existing literature on different thematic areas to fully address the objectives, problem identify and methods. It includes literature on analyze the extent of land use and land cover changes relationship with flood risk using geospatial technology. It focuses on the causes and types of flooding. Also, mentioned are some of the flood disaster in Ethiopian and case study area.

2.2. Land Use and Land Cover Change

Increased run-off as a result of LULC changes can affect the frequency of flooding, base flow and annual average flow in such a way as to alter the hydrological cycle (Birhanu et al. 2019 and Fu et al. 2019).

Changes in either land cover and/or land use do not necessarily mean that one is explicitly a consequence of the other. It is therefore improper to conclude that land cover change (LCC) occasioned by use of land explicitly degrades the land as the changes could have positive impacts depending on the use that the land is put (Turner, M. G., 1989). Many dynamic land use patterns are driven by different social-economic aspects and result in changes that affect biodiversity, water resources, and other processes, which combine to alter the atmosphere and the environment at large (Riebsame *et al.*, 1994).

The main cause of LCC in the world today is as a result of direct human use of land resources; including urbanization, rural development, forest clearing, agriculture and livestock rearing, among others. Apart from human causes, other factors that lead to LCC are changes in climatic patterns and variability, ecosystem alterations and natural hazards such as floods and fires (Meyer, W. 1995).

According to (Turner, M. G., 1989), conversion and modification of land surfaces are the main types of LCC. The former involves the complete removal of a cover type and replacing it with another. The latter can be involves a change from one type of cover to another e.g. through deforestation for the purposes of agricultural expansion (Meyer, W. 1995). Modification involves the altering of the structure or functioning without shifting totally from one type to another. Modifications affect land cover character without necessarily changing the overall land cover, for example increasing the housing density in a settlement, this leads to people live in vulnerable flooded area(Zeleke, G. and Hurni, H. 2001).Plant cover and litter on the ground surface plays an important role in intercepting rainfall during precipitation events thus reducing the impact associated with rainfall (Okoth, D. 2010). Therefore, vegetation cover helps in reducing alterations on the earth's surface as it helps reduce the ground's vulnerability to soil erosion and providing extra bond to soil, either through its roots or indirectly by altering the rates of infiltration, runoff and evapotranspiration that occur this reduced infiltration capacity of flood (Meyer, W. 1995). Total removal or alteration of vegetation therefore impacts negatively on the balance that exists between runoff, infiltration and precipitation (Okoth, D. 2010).

In their study, Ochola *et al.*, (2012), established that the massive deforestation of mangrove forests as a result of Salt Mining activities in Magarini, Kilifi led to migration of native avian species making them unavailable to those who relied on them for livelihoods. This is because these forests acted as important sources of herbal medicine, food, pasture and herbal medicine, all of which support the people's livelihoods. In addition, the areas are excavated and flooded to form salt pans which make them inaccessible for human use.

A study conducted by Onywere *et al.,* (2011) to establish the challenges posed by growth of settlement areas in Budalangi and Yala Swamp established that the creation of more estuaries at the mouth of River Nzoia was as a result of siltation. The changes assessed with the use of multi-date Landsat images occurred due to shifts in land cover characteristics; especially due to an increase in farming activities and settlements in the area. This greatly reduced the size of the areaunder water bodies. Human settlement in these areas exposes them to flooding as the area is a flood plain. The area experiences floods during the long rains (April to July) period which leads to loss of lives and destruction of property (KRCS, 2013).

As Lillesand, et al., (2008), explained remote sensing is defined as the science of acquiring information about an object through the analysis of data obtained by a device that is not in contact with the object. The instruments used for measuring electromagnetic radiation are called

sensors. These sensors record the reflected radiation from the surface of the earth and will be used for many analyses; one of these is land use land cover change analysis.

The image processing can broadly be categorized into: pre-processing and image classification (Jensen, J. 2004). The most common pre-processing techniques in remote sensing data include radiometric, spectral enhancement and geometric correction (Jensen, J. 2004; and Lillesand et al., 2008). Urban land cover mapping and subsequent quantitative change detection required geometric registration between TM and ETM scenes, and radiometric rectification to adjust for differences in atmospheric conditions, viewing geometry and sensor noise and response (Lillesand et al., 2008). One of the pre-processing of satellite image is making geometric corrections before data base creation. Geometric correction addresses errors in the relative positions of pixels. It is undertaken to avoid geometric distortions from a distorted image.

According to European Commission (2001), there are many different approaches to classifying
remotely sensed data. Image classification is the process of categorizing the pixels of an image
into a specific number of individual classes based on set criteria. Categorization is primarily based on the spectral patterns and radiance measurements obtained in the various bands of the individual pixels in an image (Lilleesand et al., 2008). However, in common image classification, there are two main classification namely unsupervised and supervised classification (Jensen, 2004). In unsupervised classification, an algorithm is chosen that will take a remotely sensed data set and find a pre-specified number of statistical clusters in multi-spectral or hyper-spectral space (Ismail et al., 2009). The main purposed of unsupervised classification is to produce spectral groupings based on certain spectral similarities. Both the supervised and unsupervised classifications use the services of a classifier algorithm of which the maximum likelihood is the most popular (Lillesand et al., 2008). Maximum likelihood is actually the probability that a pixel belonging to specific classes. It is a statistical decision rule that examines the probability function of a pixel for each of the classes, and assigns
the pixel to the class with the highest probability and is perhaps the most widely used classification methods. It is one of the most popular methods of classification in RS and usually
provides the highest classification accuracies (Ismail et al., 2009).

Practically, the supervised classification approach will select groups of training pixels that are representative for the six land cover units. This training data set forms the basis for classification
of the total satellite image, by using the maximum likelihood classifier (MLC). In unsupervised
classification approach, isodata clustering is commonly used, in which clusters of pixels based on their similarities in spectral information are automatically classified into the desired number
of LULC categories.

2.3. Landsat Image Processing

A set of Landsat 7 Enhanced Thematic Mapper (ETM+) and Landsat 8 Operational Land Imager (OLI) images was used to generate spatial information for 2009 and 2019 respectively. The two different year's 2009 thematic mapper (ETM+) and Landsat 8 OLI (2019) Satellite images were obtained from the Ethiopian Geospatial Information Agency (EGIA) to cover the one decade. Data selection was on the basis of availability of images devoid of clouds, clarity and for analysis land use/land cover for elongated time duration. Images taken during this period have less cloud cover and most of the annual croplands are fallow which is of benefit in discrimination of other land cover classes.

Ethiopian Geospatial Information Agency (EGIA) collected the satellite images from the United States Geological Survey (USGS), which freely offers the Landsat Orthorectified data collection which consists of a global set of high-quality, relatively cloud-free Orthorectified ETM+ and Landsat OLI imagery therefore there is no need for geometric correction but checking of the position was made using scanned Toposheet of 1:50,000. After the satellite images were georeferenced and radiometrically corrected. In this research the false color composite image made using Landsat ETM+ bands 4-3-2 (R-G-B) and OLI 4-3-2 (R-G-B), were found to be best for the identification of major land cover classes and extracting in the study area, were carried out, then image interpretation was performed.

Table 2. 1. Landsat image characteristics

Dataset	Resolution	purpose	Year of acquisition

Landsat 7 ETM+	30 × 30(m)	Classification	21/01/2009
Landsat 8 OLI	30 × 30(m)	Classification	05/12/2019

Source: Ethiopia Geospatial Information Agency (EGIA)

2.3.1. Image Preprocessing

The preprocessing procedure carried out on the images included band combination (layer stacking) and radiometric correction. This provided for different band combination during image classification and therefore allowing ease with which images were interpreted. The outline of the map for Akaki Kality was then used to clip the images to fit the area of study.

Image enhancement**:** Image enhancement is the process of making an image more interpretable for a particular application. Enhancement makes important features of raw, remotely sensed data more interpretable to the human eye. Enhancement techniques are often used instead of classification techniques for feature extraction studying and locating areas and objects on the ground and deriving useful information from images. The image enhancements which has been done in this study were radiometric correction analysis for the enhancement of identification of each of the land cover types.

2.3.2. Image Classification

To perform the classification the maximum likelihood supervised classifier was employed. The

samples for the training area were based on the explanation of which is a minimum of 50 samples for each map class should be collected for maps of less than 4,046.9 km^2 and fewer than 12 classes (Lillesand et al.,2008). Therefore, by considering the area of Akaki Kality sub-city(123.454km^2) and Five LULC classes (Settlement, Grassland, forestland, cultivated land and Wetland) a minimum of 50 samples per LULC category were used (Ayenew, E.2017). In Supervised Classification, the classification process has been controlled by creating, managing, evaluating, and editing signatures using the signature editor. Signatures are specific areas to which the names are assigned for supervised classification. Signatures are used to break the different classes like forest, cultivated, water and the like classes into as many subclasses as per classification requirement. Some tools such as the Signature Editor require were grown using an AOI layer which were created in the layer creation option. Based on information from previous research in the study area five different types of land use and land cover have been identified for Akaki Kality Sub- city. Therefore, five classes were identified namely settlement area, grassland, forestland, cultivated land and wetland. Then check accuracy of classified image for 82 and 115 points were generated randomly and creating GCP for 2009 and 2019 supervised image, respectively. Reference point and Ground Control Point (GCP) was crated on the classified layer on Arc GIS 10.3 then using conversion tools convert layer in to kml file. Finally check reference points for classified image by using integrating Arc GIS 10.3 and Google Map Pro then check the accuracy of classified image.

Table 2. 2. Type of LULC and Description

Type of LULC	Description
Grasslands that	Areas covered with grass used for grazing, as well as bare lands have little grass or no grass cover and shrubs.
Forestland	Planted forests, Riverine forest land, covered with Eucalyptus trees, Open forest, dense forest and mixed forest
Settlement	Villages, commercial/ residential structures, built-up area industrial sites and streets/roads
Cultivated land	Areas used for urban agriculture (both annuals and perennials)
Wetland	Akaki rivers and its main tributaries, ponds, lakes, streams and marshy area, in general waterbodies

Source: Modified from Mustard *et al.* (2004)

2.3.3. Accuracy Assessment

Accuracy assessment is an important step in the image classification process. Land use/ Land cover classification is not free from errors. Errors may appear from the method of image capturing to the classification technique implemented. Thus, image classification needs accuracy assessment at last. The accuracy assessment were be done by using generating reference point on the classified land use/land cover on Arc Map by integrating Google Earth Pro. This information was particularly important during classification of images and helped in identification of features to achieve maximum accuracy during the classification process.

From different methods of classification accuracy assessments, the dominant and mostly used classification error matrix or a confusion matrix were produced. The overall classification accuracy and overall Kappa statistic were calculated. The overall accuracy is calculated the total number of corrected classified pixel (diagonal) divided by the total number of observed pixels. The Kappa coefficient implies the errors that may come with simple random classification and over all classification accuracy reveals that the amount of classification accuracy. In addition, producer and user accuracy were attained from the matrix created. Producer's accuracy is calculated as the total numbers of correct classified pixels in each category divided by the total numbers of pixels of that category as derived from the reference data (i.e. the column total) times one hundred. This accuracy measure indicates, the probability of a reference pixel being correctly classified. On the other hand, if the total number of correct classified pixels in each category is divided by the total number of pixels that will be classified in that category (i.e. the raw total) times one hundred, it is said to be user's accuracy or reliability (Congalton, R. 1991).

$$\text{Kappa coefficient} = \frac{N\sum_{i}^{r} - \sum_{i}^{r}(xi{+}x{+}i)}{N^2 - \sum_{i}^{r}(xi{+}x{+}i)}$$

N is the total number of observed pixels

r is the number of rows

xi is the number of observations in row i and column i,

xi+ and **x+i** are the marginal totals of row and column

2.3.4. Land Use/Land Cover Change Analysis

After the data is collected from various sources, the data will be analyzed by using different software‘s like Arc GIS 10.3 and ERDAS Imagine 2015. The cross tabulation in the spatial analyst module of the ArcGIS will be employed to drive the change matrix. The change from 2009 to 2019 will be tabulated in matrices. Change analysis will be computed by comparing values of area of one data set with the corresponding value of the second data set in each period. The values were presented in terms of kilometer square and percentage. Quantification of the rate of change has been applied to generate information about the land use/land cover dynamics of the study area. The rate of change of each land use and land cover can be calculated using the following formula (Ayenew, E. 2017**)**.

$$\text{Change} = \frac{x-y}{y} \times 100$$

Where:

x= recent area of land use land cover

y= previous area of land use/land cover

2.4. Geospatial Technology based Computation of Flood Risk Maps

All disasters occur on physical space and have a spatial extent. In disaster preparedness, there is no contention that there is need for enough information regarding floods and flood vulnerability (Ouma, O. and Tateishi, R. 2014). GIS also produces a good visualization of flooding and provides an opportunity to conduct more analysis on floods and to give an estimation of the likely damage occasioned by a flood (Yahaya *et al*., 2010). Effective management of floods requires proper identification of areas of flood vulnerability (Ishaya *et al*., 2009). This helps in preparedness, putting into place preventive measures and responding to flood events (Yahaya *et al*., 2010). There are many end users of information in the flood risk maps including the government for planning purposes. Flood risk maps can be used to identify the required intervention measures and provide safety precautions meant for livelihood activities and the public safety at large (Ishaya *et al*., 2009).

According to (Jeb D, and Aggarwal, S. 2008), flood risk maps are important in many ways, they help in the enlightening on the flood risk or impacts. They help in proper visualization of the problems associated with floods in the area of interest and are also used in planning for mitigation measures. Flood risk maps also generate vital information used by planning authorities in formulating land use policies and planning for development (Forte *et al.*, 2006). In flood events, the most affected areas can be identified from flood risk maps to assist in rescue efforts, visualization and assessment of the extent of damage to facilitate in compensation of the affected persons and in evaluation of the total cost of loss or damage (Jeb, D. and Aggarwal, S. 2008).

In many parts of the world, GIS has been used in the generation of flood risk maps showing vulnerability to flooding (Ouma, O.and Tateishi, R. 2014). Such maps have been used as an important criterion for carrying out major interventions especially in the developed countries (EC, 2007). Remote sensing technology is used in collating satellite data (Ouma, O and Tateishi, R. 2014). The technology is then used to identify, classify, map, monitor, plan, mitigate and guide in management of natural disasters (Jeb, D. and Aggarwal, S. 2008). Remotely sensed data is integrated into Geographic Information Systems (GIS) analysis and eventual production of flood risk maps (Forte *et al.*, 2006). Historical datasets such as images and photographs are used in identifying the spatial extent and type of LULCC in order to assess impacts of the changes on floods (Jeb, D. and Aggarwal, S. 2008). To investigate flood risks and mitigation measures that require prioritization on the Kosi River Basin in India, (Jeb, D. and Aggarwal, S. 2008), used a GIS environment using datasets from different sources including; district level maps, topographic maps and population census data, DEM and Remotely Sensed images. The parameters applied and used in evaluation of risk and in the production of hazard prone areas in their study were drainage buffers, elevation, land cover characteristics, geomorphic characteristics and population density. Their study concluded that for a flood to occur, several factors have to act in play or combine.

Ochola *et al.,* (2010), used GIS techniques to conduct flood vulnerability assessment and delineate flood risk zones for schools in the Nyando River Catchment, Kenya. The study applied a weighted ranking procedure that utilized soil type, buffer zones, rain distribution, land use type, slope/altitude, drainage density and participatory flood maps as parameters of assessment. The study found that drainage density, soil structure, slope and rain distribution were the most influential factors in the formation of floods in the area.

According to (Ouma, O. and Tateishi, S. 2014) in their study identified the flood prone areas and conducted a detailed risk assessment using integrated approaches and GIS in Eldoret Municipality. The study found out that to map out flood prone areas, several aspects have to be incorporated including the steepness of an area, stream density, LULC and type of soil. Susceptibility to floods in Eldoret town is occasioned by an increase in the size of urban areas coupled with poor drainage systems and alteration of natural drainage system.

In the present study, all thematic layers were integrated in ArcGIS 10.1 platform to create a map depicting different flood risk zones. The input layers were obtained from the following thematic maps: land use and land cover, soil type, slope angles and elevation, rainfall distribution and drainage density. Each of the pixels in the final integration layer were regrouped into different classes with equal class intervals to divide the area into different zones. Thematic maps are usually reclassified to create integer values instead of ranges/ themes to be used as themes in the model (ESRI, 2010). The layers obtained from the reclassified land cover classes, the soil map, rainfall map, the stream density and the reclassified slope angles were then added together by overlaying all the thematic layers using the weighted overlay method with the help of the spatial analyst tool in ArcGIS 10.1 to generate a flood risk map. All the thematic layers were considered to have the same probability of influencing flood formation and thus were assigned the same weights. The choice of weights is as a result of individual opinion and a review of existing literature that gives all the parameters an equal chance to generate a flood as there is no standard formula to generate the weights (Ouma, O. and Tateishi, S. 2014).

2.5. The Concept of Flooding

2.5.1. Flood Risk Assessment

Flooding has many different definitions among which (Jennifer, M.2004) definition is worth mentioning. Flooding defined as flooding is ‘the accumulation of water within a water body and the overflow of excess water on to adjacent flood plains, or it is an overflow of inland or tidal waters, unusual and rapid accumulation of runoff or surface waters from any source’. In addition to this, flooding is an overflowing or irruption of a great body of water over land surface that temporarily inundates an area (Jennifer, M.2004).

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

2.5.2. Causes of Floods

Caused flooding of the Blue Nile River. The Ethiopian Meteorological Service re (Jayaseelan, A.T, 2001)reported on July totals >400 mm across western districts, with daily totals >100 mm and seasonal totals up to 2,000 mm. The United Nations reported 620 fatalities, ~35,000 displaced and ~118,000 people 'affected' by flooding in 2006. Since late July 2006, unusually heavy rains resulted in flash floods and overflow of rivers and dams which affects 199, 000 people in eight regions of Ethiopia, resulting in loss of life. Damage to property, and destruction of livelihoods for tens of thousands of people (Enyew, B and Steeneveld, G. 2014).Stream flow at any given point in a channel depends on the interaction of a number of factors, the most important of which are: distribution, intensity and duration of precipitation, vegetative cover, soil type, and geology of an area and topography; which includes elevation, slope and channel characteristics. Poor land use can impact on water resources by altering the hydrology (run off, infiltration and recharge rates) and increase soil erosion leading to increased sediment transport and deposition (Teller, H.L. 1967).

2.5.3. Types of Floods

The country experiences two types of floods: flash floods and river floods.

Flashfloods: are more common in areas with a dry climate and rocky terrain because lack of soil or vegetation allows torrential rains to flow overland rather than infiltrate into the ground. Often, they are sudden and appear unnoticed. is the ones formed from excess rains falling on upstream watersheds and gush downstream with massive concentration, speed and force.

This flood occurs when runoff from excessive rainfall causes a rapid rise in the water height (stage) of a stream or normally-dry channel. Therefore, such floods often result in a considerable toll; and the damage becomes especially pronounced and devastating when they pass across or along human settlements and infrastructure concentration. The recent incident that the Dire Dawa City experienced is typical of flash flood (DPPA, 2006).

River Floods: is generally more common for larger rivers in areas with a wetter climate, when excessive runoff from longer lasting rainstorms and sometimes from melting snow causes a slower water level rise over a larger area. Such flood also can be caused by ice jams on a river or high tides, but most floods can be linked to a storm of some kind. Rivers flood when the amount of water in them exceeds the flow capacity of the river channel. Most rivers have a natural floodplain into which the water spills in times of flood. Flooding can either develop gradually or rapidly according to how steeply the ground rises in the catchment and how fast water runs off into surface watercourses. On the other hand, much of the flood disasters in Ethiopia are attributed to rivers that overflow or burst their banks and inundate downstream plain lands. The flood that has recently assaulted Southern Omo Zone is a typical manifestation of river floods (DPPA, 2006).

2.6. Role of GIS and Remote Sensing for Flood Risk Assessment

Nowadays GIS is emerging as a powerful tool for the assessment of risk and management of Natural Hazards. Due to these techniques, natural hazard mapping can be prepared now to delineate flood prone areas on the map. Such kind of maps will help the civil authorities for quick assessment of potential impact of a natural hazard and initiation of appropriate measures for reducing the impact. Such data will help the planners and decision-makers to take positive and in time steps during pre-disaster situation (Yirga, K. 2016).

Spatial data stored in the digital data base of the GIS, such as a Digital Elevation Model (DEM), can be used to predict the future flood events. The GIS data base may also contain agriculture, socio-economic, communication, population and infrastructural data. This can be used, in conjunction with the flooding data to adopt an evacuation strategy, rehabilitation planning and damage assessment in case of a critical flood situation. Flood risk assessment requires up-to-date and accurate information on the terrain topography and the use of the land. Remotely sensed images from satellites and aircrafts are often the only source that can provide this information for large areas at acceptable costs (Woubet, G. and Dagnachew, L. 2011). According to (Woubet, G. and Dagnachew, L. 2011) in their study on flood hazard and risk assessment in Fogera Woreda investigated that, the major flooding causative factors particularly in Fogera Woreda are slope condition of the area, soil type, elevation, land use type, drainage density, and rainfall.

2.7. Flood Risk Areas in Ethiopia

The past, there have been floods which have taken both human lives and destroyed properties. As a result of prolonged and intensive rainfall, the soil in most areas, particularly in the western, central highlands and northwestern parts of the country became saturated causing an overflow of rivers and flash floods in many areas. **Abay River Basin**: Overflow of Rib and Gomara rivers and Lake Tana in Libo Kemekem and Fogera woredas of South Gonder, Bahirdar Zuria and Bahidar town of West Gojjam and flash floods in Dewchefa and Ansokiya woredas of Oromiya and North Shewa zones, respectively, displaced people from their residential places and forced them to stay under temporary shelter. Currently, there are a total of 13,362 people reported to be under temporary shelter in the region (DPPA, 2006).

Awash River Basin: Flooding of the upper basin of Awash river affected 14 peasant associations (PAs) in Sebeta Hawas, Ilu, and Ejere woredas of Oromia region. The flood was reported to have affected a total of 14,790 people out of which 2052 people were displaced and forced to live in temporary shelters. On the other hand, heavy rainfall in the central highlands in the coming weeks is considered as a major threat around the major dams in the basin (Koka). The dams are already full and contain excessive water. Some of them have already started to overflow. The heavy rains in the highlands of East Hararghe Zone of Oromiya Region caused flash flood from the overflow of Dechatu dry season stream that hit Dire Dawa town in the middle of the night on the sixth of August 2006, while residents were asleep. According to the Dire Dawa Administration, the flood affected over 9,000 people and killed 256 others. The death toll was largely due to the fact that the flooding took place at a time when people were in deep asleep. Currently, over 6,000 people have been temporarily sheltered in six sites, including schools and other compounds. It has also washed away houses and properties of many people living along the riverbank. Roads, bridges and other public properties were damaged and washed away. The estimate of overall loss or damage of properties of individuals and infrastructure is recently disclosed by the Administration to be Birr 27 million (DPPA, 2006).

Baro-Akobo River Basin: Reports of an overflow of Baro river have been received from the Region. Areas affected by the flood are Gambella Zuria, Jikawo, Itang and Gillo woredas. So far, the impact of the flood on human beings is not yet serious. However, it has affected a large area of crop fields. Flooding in Gambella is normal but its occurrence at this time of the year is somewhat early. All rivers in the Region are full. High rainfall in the coming weeks in the western highlands could cause severe flooding. Generally, the situation in the Region is worrisome calling for close monitoring and follow-up (DPPA, 2006).

Omo-Gibe River Basin: The extraordinary overflow of Omo river in August severely affected about 8,000 people in Dasenech and Gnangatom woredas of South Omo Zone. It has also killed 364 people and swept away some 3,200 cattle and destroyed other properties, including 760 traditional grain stores. This area is one of the worst affected as compared to others in the country. Efforts have been underway to rescue and save the lives of those stranded and also find the bodies of those drowned by the flood. Furthermore, flashflood from Bilate river was reported to have affected 5370 households in Humbo Woreda of Wolayita Zone out of which 2,515 households were severely affected and require immediate emergency assistance. Moreover, landslides due to heavy rainfall were reported from Guraghe and Kefa zones although their impact was not as serious as that of the floods (DPPA, 2006).

2.7.1. Urban Flooding in Addis Abeba

Addis Abeba is the capital and the largest city in Ethiopia, with a population of about 2,800,000, according to the 2007 population census. The city is situated on the high plateau of central Ethiopia which is aligned with the North–South-oriented mountain systems neighboring the Rift-Valley. The City is overlooked by Mount Yarer in the east, Mount Entoto in the north and Mount Wochecha in the west. Several small streams originate in the mountains surrounding the city and flow into the metropolitan area of Addis Ababa. Torrential rains, which are common during the rainy season, cause a sudden rise in the flow of these streams and periodically inundate the settlements built along their banks. The flooding of August 2006 was the worst in Ethiopian history. It affected 363,000 people and left approximately 200,000 people homeless (DPPA, 2006). The final death toll was estimated at around 647 but the impacts on health and well-being were much larger. Historically, Addis Abeba the capital of Ethiopia, is recognized as one of the largest Cities in Africa. The uncontrolled growth and unplanned urbanization has brought severe socio-economic, cultural and environmental problems (UNCHS, 2007). The significant expansion of the built environment, deforestation inadequate urban planning, squatter settlements and the poor integration between road and urban drainage infrastructure are the major causes of flooding. Flood risk is exacerbated since the foundation and expansion of Addis Abeba, which is closely associated with rapid urbanization practices trigged by the reduction of croplands, increase in runoff generation, uphill deforestation and the limitation of urban drainage infrastructure which was contribute to flooding. The Big Akaki and Little Akaki are the major rivers that flows through the cities from north to south and constitute the Akaki river basin. Flooding is prevalent in Addis Abeba because the topography with steep mountainous and low-lying flood plains and the heavy rainfall that occur during the kiremt rainy season.

Figure 2. 1. Flooded road in Addis Ababa, Ethiopia

2.7.2. Flood Risk in Akaki Kality

Flooding from rivers, estuaries and the sea pose a serious threat to millions of people around the world. Problems related to flooding and vulnerability of the Akaki Kality sub-city were greatly increased in recent decade due to several factors including changes in landuse in the urbanization of flood-prone sites, house constructed near to river and substandard constructions, and increased household density. As a result, the overland surface water runoffs increased from time to time. This is due to the fact that roads, homes, and buildings, do not allow rain water to be absorbed into the ground (AACFEPRA, 2018).

Figure 2. 2. The Akaki River through Addis Abeba

2.8. Digital Elevation Model (DEM)

A DEM was obtained from the CIAT-CSI SRTM (http://srtm.csi.cgiar.org) as provided by (Jarvis *et al*., 2008) through the Regional Center for Mapping of Resources for Development (RCMRD) and in decimal degrees and in WGS84 Zone 37N datum. This data had a resolution of 30m. The data was projected into the UTM coordinate system and clipped to fit the extent of the study area. Information obtained from the DEM included the elevation, stream network for the area, watershed extent, water basins in the area and helped in determining the flow direction and accumulation. The DEM was then reclassified to generate slope angles, elevation of the terrain and stream density which were then overlain to generate a flood risk map for the area.

In this study DEM was obtained from 5 meter contour interval feature class which is digitized from topographic map of 1:50,000 scale Akaki Kality Sub-city and further rectified in GIS environment. This feature was converted to 3D shape file using 3D Analyst in convert facture to 3D module by interpolating contour using an attribute as a source. Further TIN was created using 3D Analyst in Create TIN from feature 3D Analyst in create was created using 3D Analyst in create TIN form feature (3D shape). The slope facture class was further converted to raster using conversion tool in To Raster/ Feature to Raster module. The spatial resolution was 20m. Then this data was define projected in to UTM coordinate system adindan Zone 37N and clipped to fit the extent of the study area. Information obtained from DEM included the elevation and slope. The DEM was then reclassified to generate slope and elevation which were then identify flood vulnerability map and weighted overlay to generate/delineate flood risk map for the study area.

2.9. Multi Criteria Evaluation (MCE)

The technique used in this study and implemented in IDRISI GIS software is that of pair wise comparisons developed by (Saaty, T.L. 1977) in the context of a decision-making process known as the Analytical Hierarchy Process (AHP). It is one of the multi-criteria decision-making techniques. In the procedure for Multi-Criteria Evaluation using a weighted linear combination, it is necessary that the weights sum to one. In Saaty's technique, weights of this nature can be derived by taking the principal Eigen Vector of a square reciprocal matrix of pair wise comparisons between the criteria. Eigen vectors are a special set of vectors associated with a linear system of equations (i.e., a matrix equation) that are sometimes also known as characteristic vectors, proper vectors, or latent vectors (Eastman, J.R., 2001). The standardized raster layers were weighted using Eigen Vector that is important to show the importance of each factor as compared to other in the contribution of flood hazard. Accordingly; the Eigen Vector of the weight of the factor was computed in IDRISI 32 Software in Analysis menu of the decision support/weight module based on the given pair-wise comparison.The weighted module was fed with the pair wise comparison 9 point continuous scale. Then the principal Eigen Vector of the pair wise comparison matrix using the factors affecting flood risk was calculated. A consistency ratio values less than 0.1 is acceptable.

It can be concluded literature review on study did not only probe on the impacts of land use and land cover changes on flood risk but gives an in-depth insight into the underlying processes and technologies that can be used to generate useful flood risk maps. A review of literature on the various themes provided useful information on the idea of the relationships that exist between LULCC generation of floods. In the present study six criteria input layers were obtained from the following raster layers: slope, elevation, drainage density, soil, rainfall, and landuse. Most of researcher have the same probability of influencing flood formation and thus were assigned the same weights. Accordingly, in this study GIS was integrated with MCE they listed in order of their importance to flood hazard and they assign as different weight influence of flood risk. The consistency ratio of the calculated Eigen Vector was 0.09 that shows that the given pair-wise weights are accepted. Each was presented and stored in layer by using Arc GIS 10.3 and the criterion values are generated. The criterion maps are converted into grids (Raster) using conversion tools of Arc tool box of GIS. However, it was revealed from the National Disaster Policy that flood risk management has largely focused on flood response rather concentrating on the land use land cover processes, early warning systems and generation of information. Flood risk maps are an important component of land use planning but aren't readily available in most areas.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Introduction

This chapter forms the core of the research. It gives detailed information of the description of study area with regards to location, population, topographic feature, climatic conditions, geology, Drainage, soil characteristics and land use. The chapter also gives a detailed explanation of the sources, software used and forms of data acquired for the research, as well as the methods adopted for flood risk areas and analyze the extent of landuse and land cover change occurring in the area of study.

3.2. Description of the Study Area

3.2.1. Location

Akaki Kality is the second largest sub-city and the major industrial zone of Addis Ababa, located in the Southern part of the city. It has an area of 12345.4 hectare. The lowest elevation point 2,060 meters and the maximum elevation is 2,340 meters above sea level. Latitude and longitude GPS coordinates bounded between $8° \, 53 \, '5'' \mathrm{N}$ and $38°47'21''\mathrm{E}$ respectively. In addition to, study stated geographically limited it shares boundary with Bole Sub-cities in the North, Nifas Silk Lafto Sub-cities in the North West and Oromia Reginal States in the South and East directions.

The Akaki is a river of central Ethiopia. It is a tributary of the Awash River on the right side. Among the important headwaters of the Awash is the Akaki River, which flows through the city of Addis Ababa. The River consists of two main branches, join at Aba-Samuel reservoir until recently. The Western branch of the river, the Little Akaki, rises northwest of Addis Ababa on the slopes of Wechacha Mountain and flows for 40 km before it reaches the reservoir.

The Eastern branch of the river, the Great Akaki, rises North East of Addis Ababa and flows into Aba-Samuel Reservoir after 53 km. The important tributaries of the Great Akaki Kebena join from North. Both the Akaki Rivers are used for industrial, horticultural and domestic purposes (Habtamu, S.2011). Figure 3.1 shows that location Map of study area.

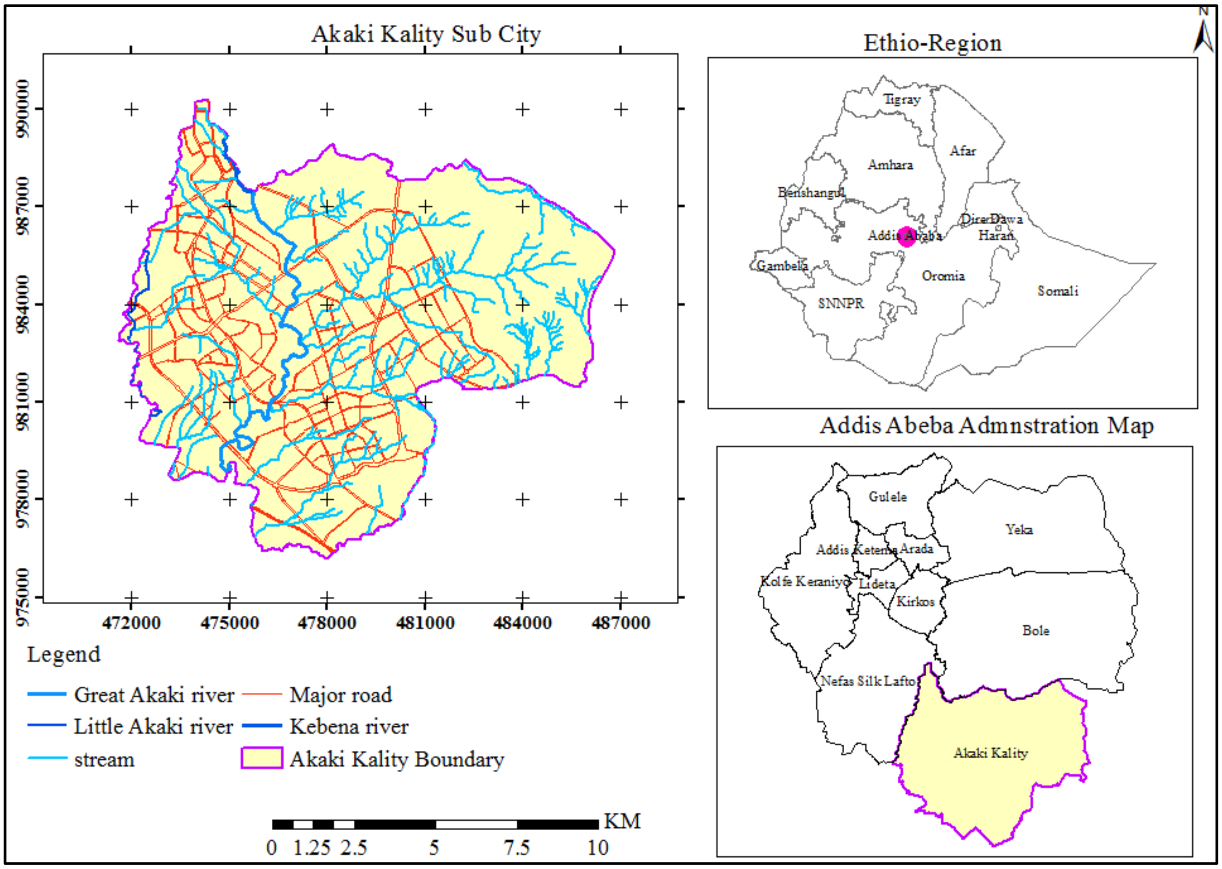


Figure 3. 1. River system and major road network map of Akaki-Kality sub city

3.2.2. Population

According to Central Statistical Agency of Ethiopia the projected population of 2014-2019, the population of the Akaki Kality Sub-city was 115,736 males and 122,619 females which aggregated to 238,355 peoples living in the sub-city. The population density of the Sub-city then was 2018.6 per sq.km. Therefore, from projection population figure below indicates that the population size increase from time to time it indicates that the people lives to bank of streams. From the figure below population projection values of from 2014-2019(CSA, 2013).

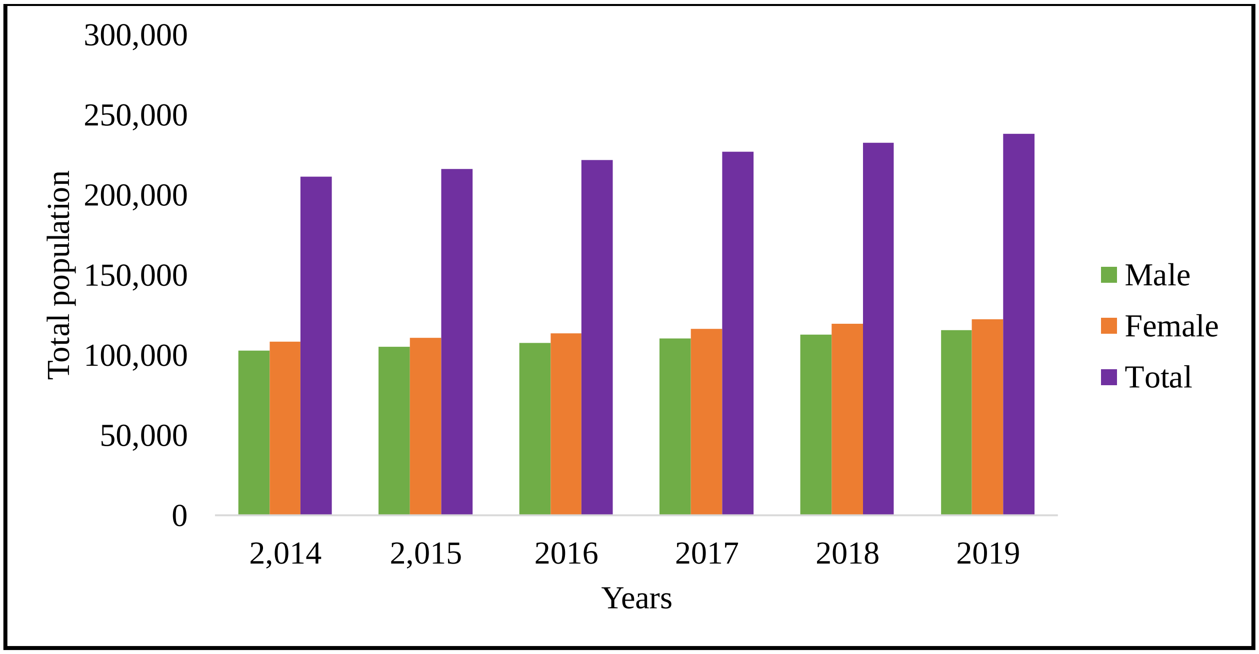


Figure 3. 2. Population projection values of from 2014-2019 by sex

3.2.3. Topographic Feature

The topography of a watershed like elevation, slope, etc. has an important contribution for the amount of flood risk generated from it. The topography feature of the area were extracted information like drainage, elevation, and slope from Topography Map of the Akaki Kality Sub-city. The elevation and slope data were digitized from contour map of Akaki Kality Topography Map. The typography of great Akaki Kality Sub-city is rugged and steep mostly North and North West part of the area but, it is gentle and flat lying in South and Southwestern parts of the area (Feyera, A. 2007). According to the extracted elevation of the study area from DEM, the boundary is located along elevation range from 2060-2340m.

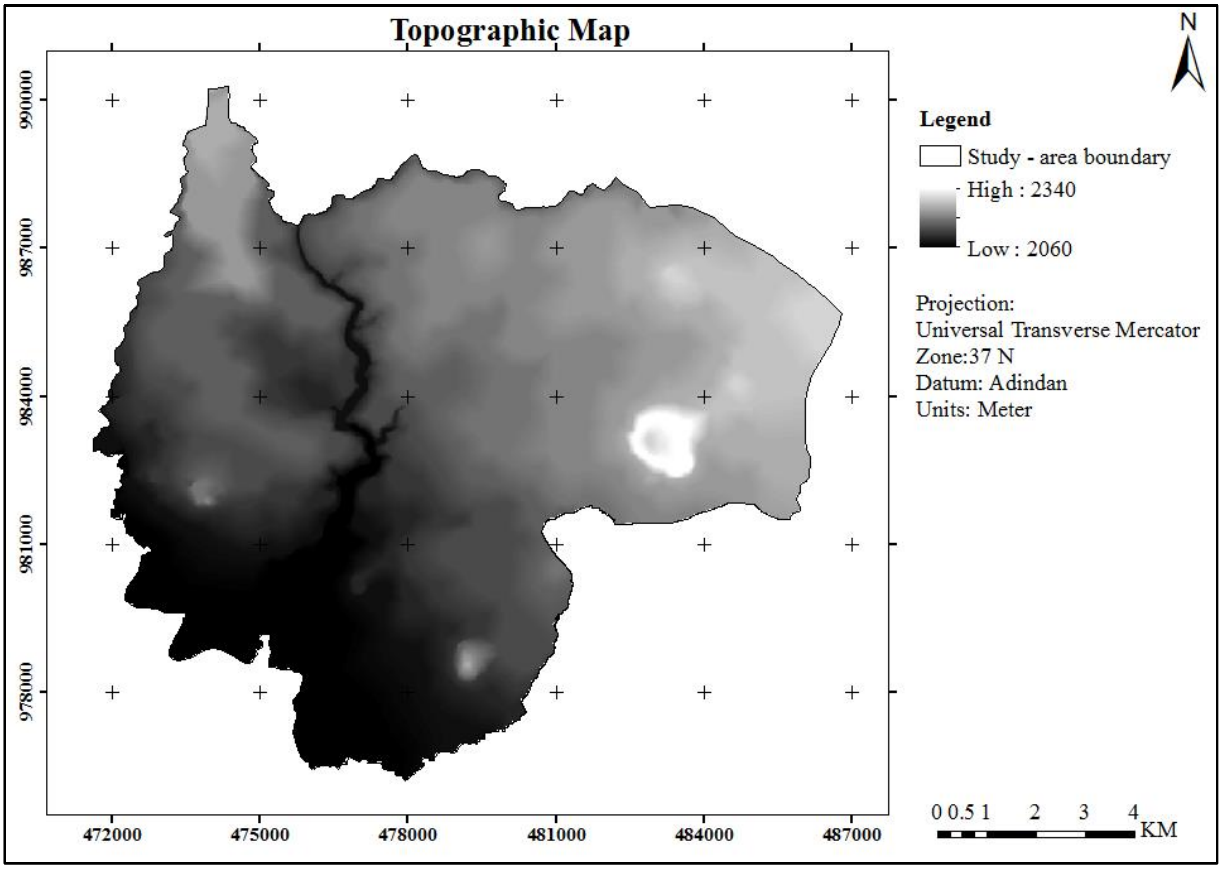


Figure 3. 3. Topography feature map of the study area

3.2.4. Climate

Climates can be classified according to the average of different variables, most commonly temperature and rainfall or precipitation. Accordingly, the present study, assessed temperature and rainfall data to determine the trend and spatio- temporal variability of climate in the study area. In addition, this study area is classified within climatic zones of Woina Degas (Berhanu et al., 2018)

Rainfall: Spatial rainfall distribution is an important factor in evaluating flood risk. The rainfall data used for this study was collected from National Meteorological Agency (NMA) of Ethiopia excel format number of sample 15 years (Appendix iii) and the data was already interpolated to create a continuous rainfall raster of the area of study (Figure 4.4). Monthly rainfall records from two gauge stations namely; Akaki and Kality gauge station the data covered the period between 2005-2019 years. Average monthly rainfall distribution of Akaki and Kality station was shown (Appendix i). The major rainy season Akaki station is from May to August but, there is relatively small rainfall during the month of December and April. The maximum and minimum monthly rainfall in Akaki station were recorded with the value of 334.4 mm and 0.2 mm in July 2010 and December 2014 respectively. In addition to, Figure 3.3 almost in this station the maximum peak rainfall is observed to be in June to August.

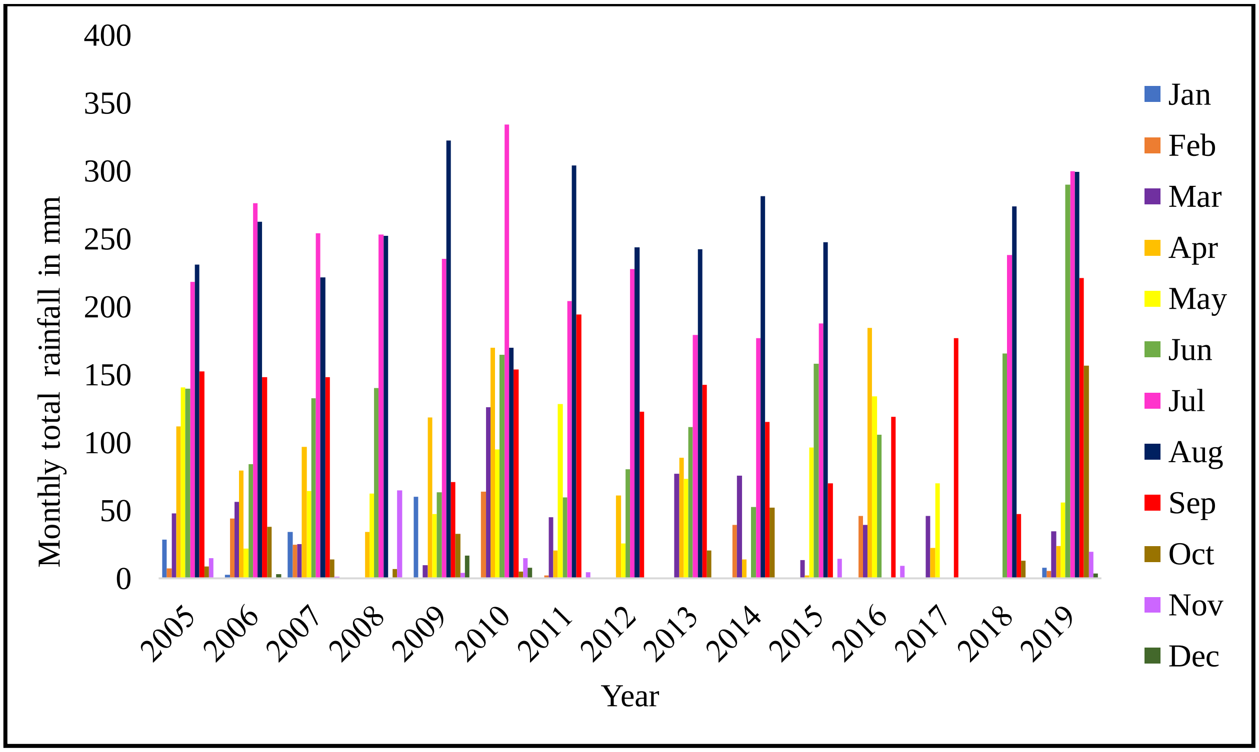


Figure 3. 4. Monthly rainfall data of Akaki station from 2005- 2019

Furthermore, from the figure below Kality station the major rainy season is from June to August but there is relatively small rainfall during the month of December to February. The maximum and minimum monthly rainfall in Kality station were recorded with the value of 391.3 mm and 1.2 mm in August 2019 and December 2017 respectively. In addition to, Figure 3.4 almost in this station the maximum peak rainfall is observed to be in July and August.

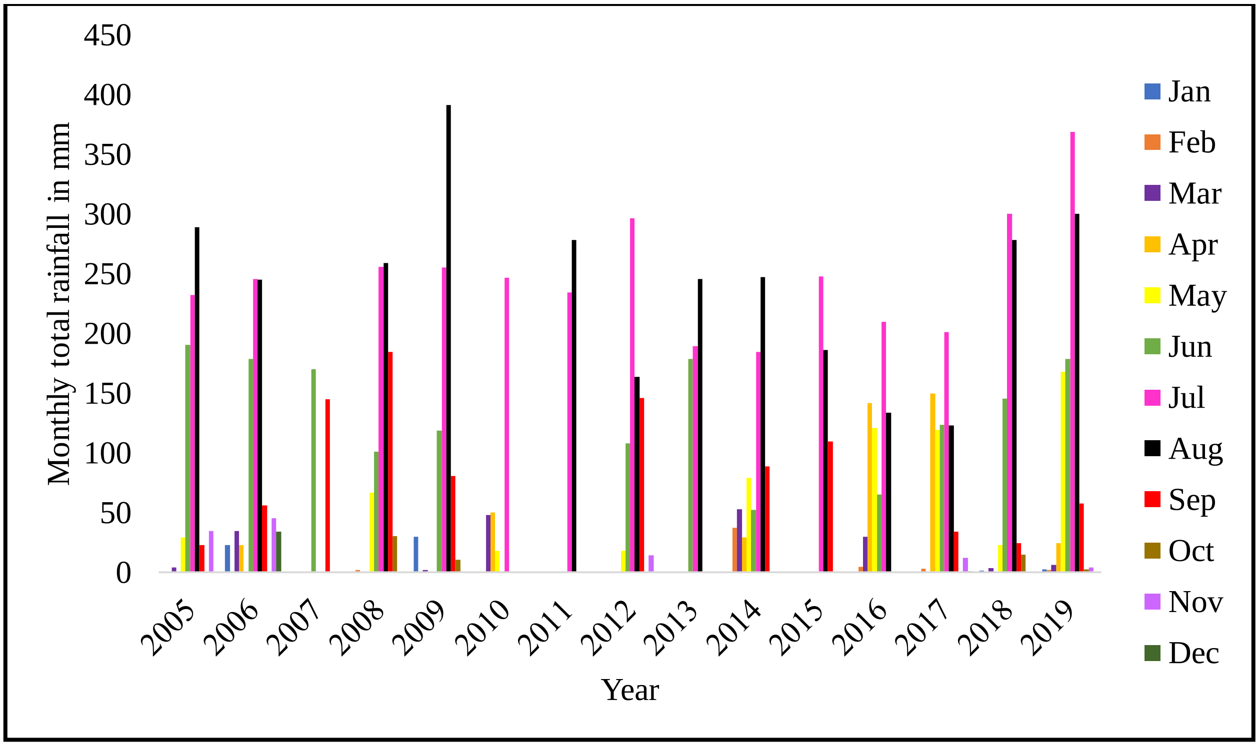


Figure 3. 5. Monthly rainfall data of Kality station from 2005- 2019

It concludes that the study area receives in Akaki and Kality station annually maximum 3353.3, 3469.4, mm and minimum 2.9, 35.2 mm total rainfall respectively. In both stations the distribution of monthly rainfall indicates that rainfall pattern in the study area is predominantly bimodal (i.e., rainfall occurs over a continuous period of times, but dominated by two rainfall peaks). Akaki rain starts from June to August and Kality from July to August. In general, the wet season starts from June to August sometimes continuous to September.

Temperature: The temperature of the area is related with altitude. When altitude increases temperature decreases, because of the earth atmosphere heated upward from lowest level. Temperature maximum and minimum data received from 2007-2018 National Meteorological Agency (NMA) of Ethiopia in Kality station. The mean monthly maximum and minimum temperature was shown (Figure 3.6). Annual mean maximum temperature was 14.9℃ and Annual mean minimum temperature was 6.6℃(Appendix ii).

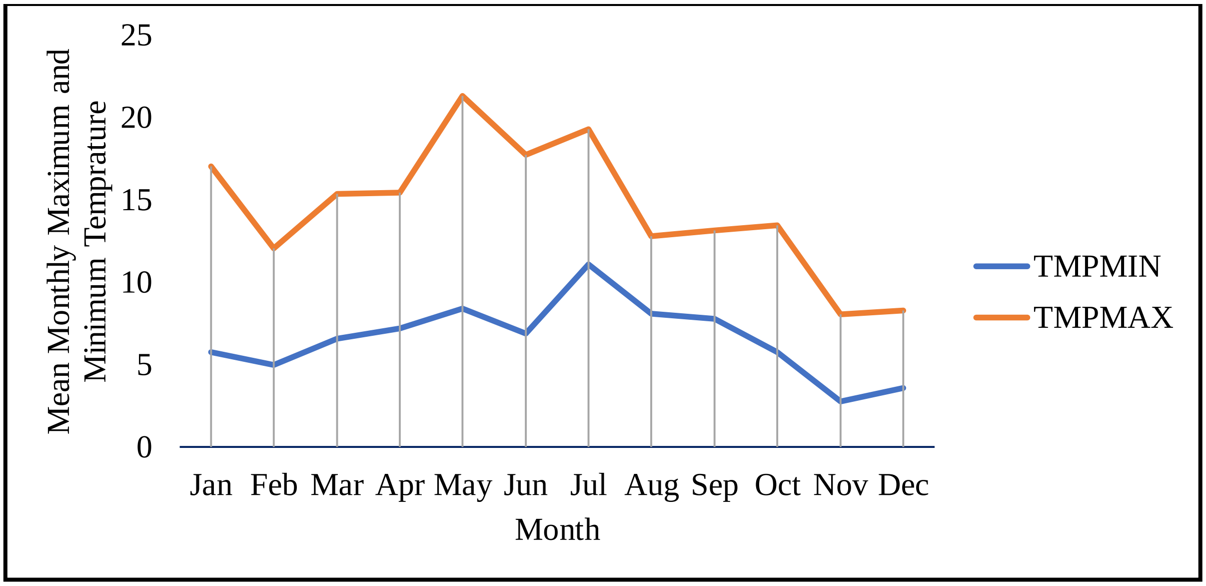


Figure 3. 6. Mean Monthly Maximum and Minimum Temperature in Kality Stations

3.2.5. Geology Characteristics

According to (Jemal, S.2009), The geology of Akaki River basin along the north and northeastern area (the Entoto mountain, the northern and north eastern Addis Ababa) is covered with basalts, trachytes, rhyolites and several episodes of pyroclastic materials of older volcanism occur on the upper part and foothill sides of Entoto ridge Overlying these, younger basaltic rocks (Addis Ababa Basalt) are found covering the central and southern part of the city. The Addis Ababa basalt covered by settlement and had low recharge. Outcrops of ignimbrites in the Eastern Addis and Central Addis have been observed underlying the Addis Ababa basalt. Furi and Yerer volcanoes are recognized overlying unconformable on the Addis Ababa basalt in the western, south-western and eastern part of the Akaki (including the well field) catchment. Alluival deposits are found in some place along the little and Big Akaki rivers, particularly South and South West of Addis Abeba (Fanuel, S. 2007).

3.2.6. Soil Characteristics

Eutric Vertosols have a topo soils consisting both the surface mulch (or curst) and the underlying structure profile that changes only gradually with depth. Eutric Vertosols in general have favorable chemical properties but, the problem of soils in their physical qualities. Under high levels of management however, some of the physical problems can be overcome and high intensities of cultivation may become possible (Tadesse, D. and Haile, D.2016). These soils are generally hard when dry and sticky when wet, a very low infiltration rate, very low saturated hydraulic conductivity and compaction as a result of swelling, and therefore presents serious limitations to their use. Crop production on these soils is limited because of impeded drainage, difficulty of land preparation, soil erosion and low fertility. Such soils may be highly suitable for paddy rice cultivation but, lack of drainage may induce salinization. Eutric Vertosols a clay soil which covered the whole area soils type the in the study area have characterized by low water available capacity, heavy rainfall, low permeability and porosity when wet, leading to low filtration and high runoff (Tadesse, D. and Haile, D.2016).

3.2.7. Drainage System

Addis Ababa lies within the Awash River Basin. The water divides between Awash Basin and Blue Nile Basin lies on the top of Entoto Ridge. The catchment area of Akaki River basin that totally includes Addis Ababa area is divided into two sub basins – the Big Akaki River (Eastern) sub basin and the Little Akaki River (Western) sub basin (Habtamu, S. 2011).Tributaries of the Little Akaki include Burayu, Gefersa, Leku, Qille, Gerbeja, Worenchiti, Melka Qorani, Kera and Jaja streams and tributaries of the Great Akaki river include Ginfile, Kebena, Kechene, Kurtume and Yeka.Streams are dense with deep valleys on top of mountains such as Entoto ridge forming radial and dendritic drainage patterns. The drainage system has been digitized from the topographic map of the area and it shows dendritic drainage patterns (Figure 3.7). The major streams form parallel drainage pattern oriented in a general North-South direction; the following streams drained to Aba Samuel reservoir.

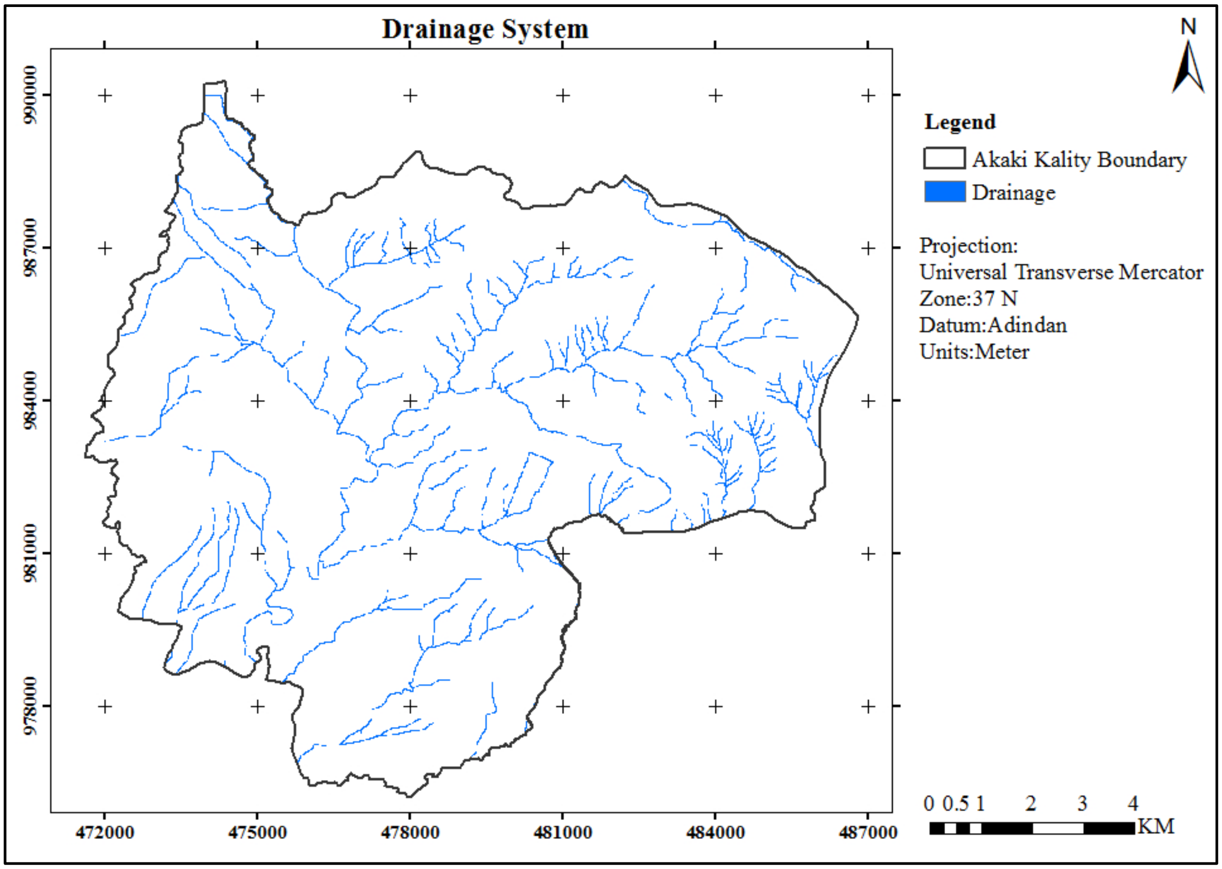


Figure 3. 7. Drainage System of the study area

3.2.8. Land Use/Land Cover

Most of the norther part of the study area was occupied by settlement, mixed land use practices and planted tree (Eucalyptus) in the up hills of the Entoto ridge whereas the southern part was dominated by non -irrigated agriculture (Tesfa,K.2019). There are different types of land use/land cover class in the study area. However, according to different literature and previous studies the land use were in the sub-city, namely: settlement, wetland, cultivated land/urban agricultural, grassland and forestland (Figure 3.7). Form the above listed land use classes the dominant one is cultivated land in the study area. The land use/land cover of the study area was classified using Satellite Pour l'Observation de la Terre (SPOT) 1.5 m satellite image. The image was georeferenced to a Projection: Universal Transverse Mercator, UTM 37 N, and Datum: Adindan. The study area was clipped from the full scene. Then the subset/clipped image was undertaken supervised classification with collected during field work 115 Ground Control Points (GCP) taken and other relevant field data collected ground truth for land use/land cover (Appendix v). The LULC classified image are presented in Figure 3.8.

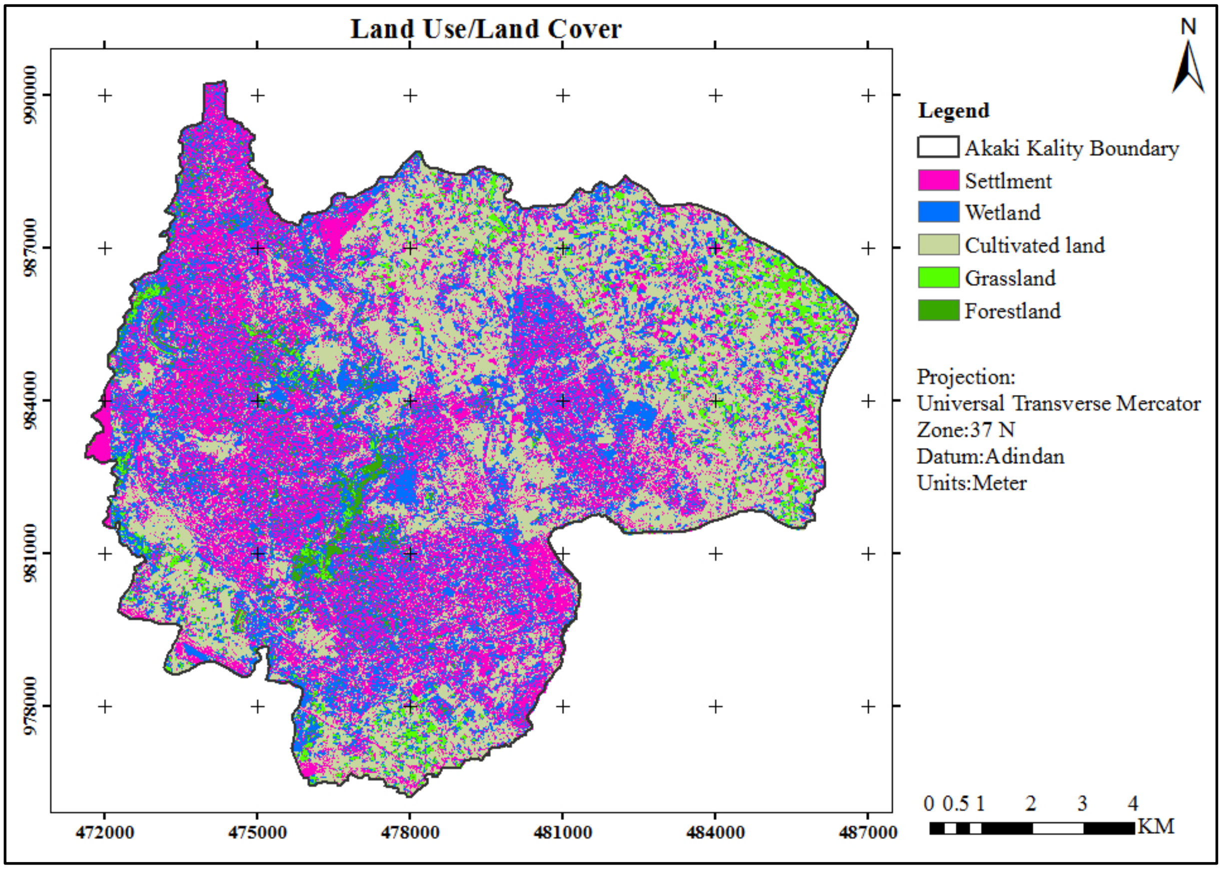


Figure 3. 8. Land use/Land cover map for study area

3.3. Source of Data

Different kinds of data have been collected to conduct this study. The collected data were from

different sources. The data from primary sources include photograph image was taken from study area and collected Ground Control Point (GCP) from on field data. Whereas, secondary data sources were obtained from request to organization, agency and institution written to formal letter application. This include such as DEM, precipitation/rainfall, Topography Map, SPOT satellite image, soil type, number of populations, administrative boundary data and satellite /Landsat image were used to carry out this study and were tabulated in the Table 3.1.

Table 3. 1. Data sources and their purpose

No	Data used	Data type	Scale	Data source	Description
1	Drainage data	Shape file (.shp)	1:50,000	Digitized from Akaki Kality topography map	To generate flood risk map
2	Boundary data	Shape file (.shp)	-	Akaki Kality Sub-city land management office	for flood risk distribution
3	Ground truth and accuracy assessment point	Point data	-	Field survey	To check the accuracy of land use/land cover class
4	Topography map	raster(.tiff)	1:50,000	Ethiopian Geospatial Information Agency	For study area location map and digitization drainage density, slope and elevation
5	Slope and Elevation data	raster(.tiff)	1:50,000	Digitized from Akaki Kality topography map	To generate flood risk map
6	Rainfall data	Excel(.xls)	-	Ethiopia Meteorological Agency	To delineate flood risk map
7	Soil data	Shape file(.shp)	-	Ministry of agriculture	To delineate flood risk map
8	SPOT image	Raster(.tiff)	1.5 m	Ethiopian Geospatial Information Agency	To delineate flood risk map
9	Satellite image	Raster(.tiff)	Landsat ETM+ and OLI (30m)	Ethiopian Geospatial Information Agency	To change analysis of land use/land cover class

3.4. Software

Software used in this study is selected based on the capability to work on the existing problems in achieving the predetermined objectives. Hence software package like ERDAS 15 was used for image processing and classification activities on satellite images. Moreover, Google Earth Pro was used to check the accuracy of land use/land cover class. Rasterization, reclassification, Weight overlay and the factor map development was carried out using ArcGIS 10.3 software package. The factors that are input to for multi-criteria analysis should be preprocessed in accordance to the criteria set to develop flood risk analysis. Therefore, using Spatial Analyst and 3D Analyst extension, some relevant GIS analyses were undertaken to convert the collected shape files. Eigen vector for the selected factor was computed using Weight module in IDRISI 32 software. Microsoft Office 2013 was used for research report writing, charts, graphs and presentation.

3.5. Methods

The technological scheme of method of data analysis shows on figure starting from top to bottom, were selected factors (criteria) in order to identify the flood venerable area. Landsat Images were image enhancement and mosaicked to generate a composite which was then clipped to extract the area of study. The clipped image was subjected to maximum likelihood supervised classification to generate LULC classified maps. The classified LULC image was to verify their Ground Control Points (GCP) taken and other relevant field data collected ground truth for land use/ land cover. All classification processes were performed in ERDAS Imagine 2015. Drainage density was digitized from Akaki Kality topographic map. Soil venerable maps were generated from the soil data, rainfall venerable maps were generated from rainfall data, while slope and elevation venerable maps were obtained from DEM data and LULC data obtained from the classified SPOT 2018 satellite image. The thematic layer on drainage density, soil, and rainfall were converted to raster format, reclassify and ranked. The flood risk analysis was computed using Multi Criteria Evaluation (MCE). To run MCE, the selected flood vulnerable factors such as soil type, elevation, slope, drainage density, land use, and rainfall were developed and weighted. The factors that are input to for multi-criteria analysis should be preprocessed in accordance to the criteria set to develop flood risk analysis. So, Eigen vector for the selected factor was computed using Weight module in IDRISI 32 software. The general workflow showing the methodology to delineate flood risk area. All these processes were performed in ArcGIS 10.3. Therefore, the flood risk map which can be reclassified into five zones, very high, high, moderate, low and very low zones. The general workflow showing the methodology to delineate flood risk area explained in the Figure 3.9 and Figure 3.10 illustrated to the summary from the acquisition of data and land use/land cover analysis and data processing of flood risk analysis respectively.

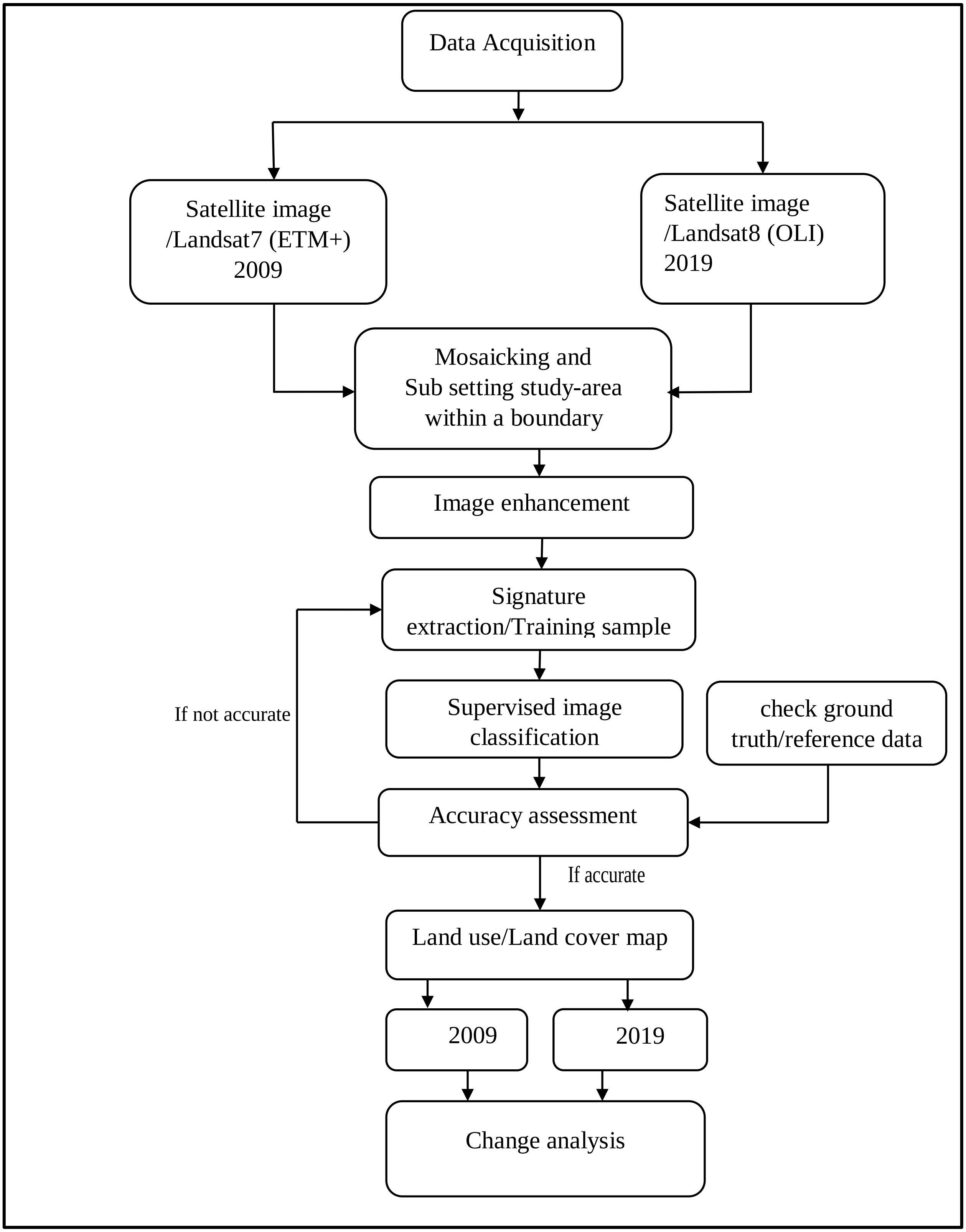


Figure 3. 9. Technological Scheme of Land Use and Land Cover Analysis

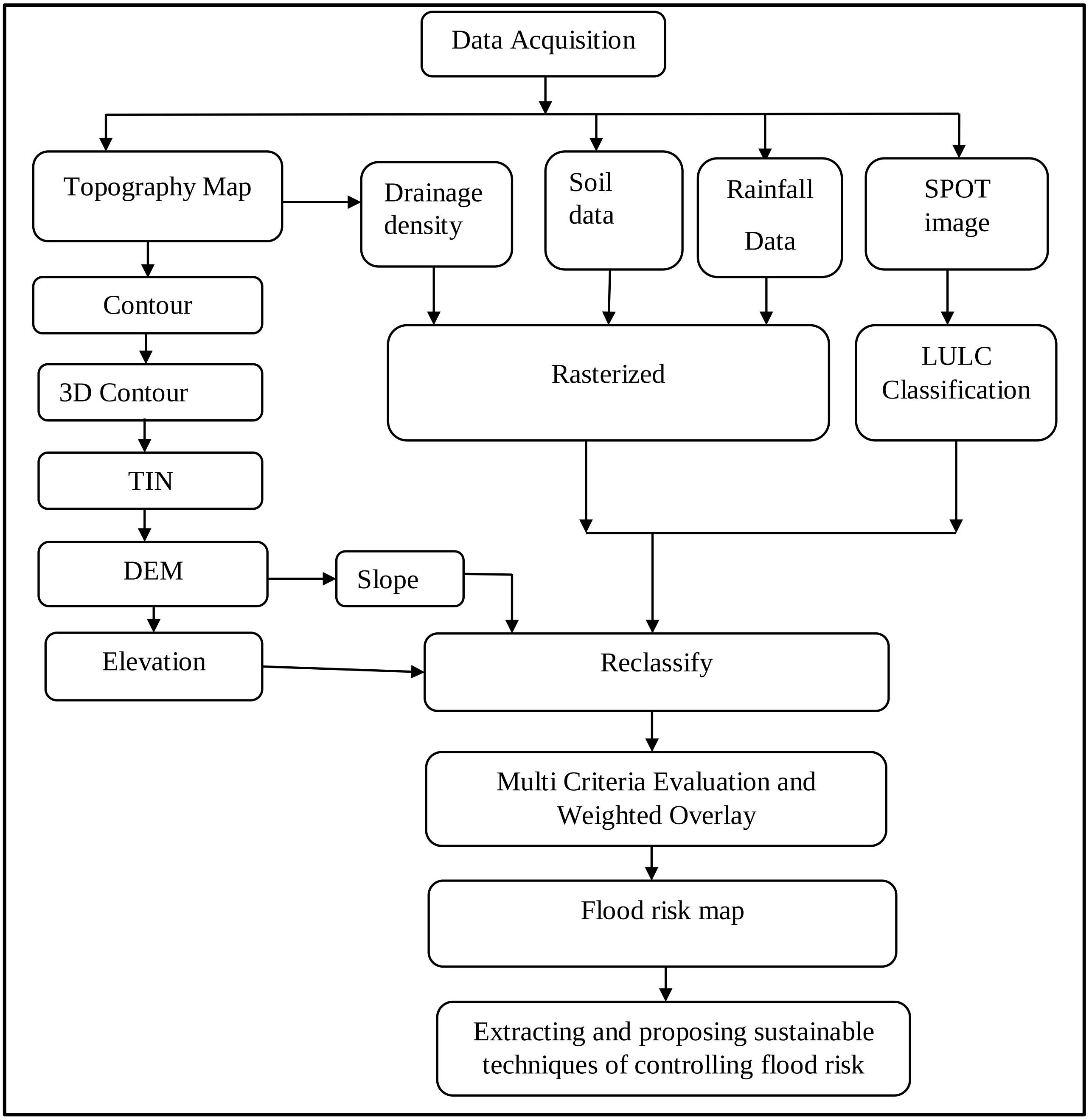


Figure 3. 10. Technological Scheme of Flood Risk Analysis

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Data Analysis and Result

This chapter presents result and finding analysis of data divided into three section based on specific objective. The first section presents analyze the extent of land use and land cover change occurring in the study area for the period of 2009 and 2019 Landsat image. The second section presents findings on the area in Akaki Kality sub-city that are flood vulnerability based on combination of factors including slope, elevation, drainage density, rainfall, soil type, and landuse. The evaluation of flood vulnerability was made after the maps of the criterion were prepared. The criterion map layer reclassified values between 1 and 5 were assigned after the reclassification, where 5 indicates very high flood vulnerability and 1 indicates very low flood vulnerability depending on the criteria's class values. The third section provides delineate flood risk map were used as Weighted Linear Combination (WLC) where continuous criteria (factors) were standardized to a common data that was raster layer with a resolution of 20 m cell size, added to spatial analysis/weighted overlay call the six raster layers to weighted overlay. Finally delineate flood risk map of case study area based on reclassified flood risk. The reclassified risk map values between 1 and 5 were assigned after weighted overlay, where 5 indicates very high flood risk and 1 indicates that very low flood risk. Finally, results are presented in form of tables, figures and maps. Finally, interpretation of those tables, figures and maps.

4.2. Land Use/land Cover Change

4.2.1. Land Use/ Land Cover Classification

Land use/land cover is an important and a predominant aspect in assessing an area's susceptibility to flood risk. The preprocessing procedure carried out on the images included band combination (layer stacking). This provided for different band combination during image classification and therefore allowing ease with which images were interpreted. The outline of the map for Akaki Kality sub-city was then used to clip the images to fit the area of study.

A set of Landsat ETM+ and OLI images was used to generate spatial information for 2009 and 2019 respectively. The two different year's 2009 thematic mapper (ETM+) and Landsat

Operational Land Imager (OLI), 2019 satellite images were obtained from the Ethiopian Geospatial Information Agency (EGIA) to cover the one decade.

Supervised image classification which is a widely used technique (Sluiter, R.2005); (Nangendo, G.2005) was applied. In this study, a supervised classification method was used, in which training samples and spectral signatures of known categories, such as cultivated land, forestland, grassland, settlement area and wetland, have to be developed. Accordingly, the two-land use/ land cover maps of the year 2009 and 2019 were generated using the widely used maximum likelihood classification algorithm (Lillesand et al., 2000). The land use/ land-cover categories in the basin were classified into five classes as presented in Table 4.1.The training samples for each land-cover class for 2009 and 2019 were selected as many as possible throughout the entire image based on composite images as well as google earth images for 82 and 115 points were generated reference points and Ground Control Point (GCP) for 2009 and 2019 supervised image, respectively (Appendix iv). The reference point and GCP was crated on the classified layer on Arc GIS 10.3 then using conversion tools convert layer in to kml file for 2009 and 2019 classified image respectively. Finally check the reference points for classified image by using integrating Arc GIS 10.3 and online Google Map Pro, then check the accuracy of classified image. This information was particularly important during classification of images and helped in identification of features to achieve maximum accuracy during the classification process. Some of the various types of plants used in cultivated land (dryland farming, such as potatoes, onions and others), tend to provide minimal vegetation cover and a high potential for erosion during rain that can affect the sedimentation and siltation of rivers in the study area. Reduced river capacity as a result of sedimentation tends to lead to the overflow of rivers and flooding. Meanwhile, the trend for year-on-year decreases in the coverage of both grassland forestland class of LULC in the area also impact on the reduction of infiltration zones, notably in the upstream areas of the study area.

According to (Rosyidie, A. 2013), one cause of flooding in the study area was the change in LULC in those upstream areas that were previously forestland and grassland have since been converted into dry land farming, comprising horticultural farms with seasonal plants such as potatoes, carrots, mustard greens, cabbage and beans that tend to require a short time to harvest. High erosion rates occur because these seasonal plants do not protect the soil from erosion and contribute to sedimentation and flooding in the lower regions. According to (Bosch, J.M and Hewlett, J.D. 1982) described the strong correlation that exists between a reduction in forested areas, or deforestation, and an increase in flooding, whereas (Wan, R. and Yang,G. 2007) explained how the expansion of urban/built-up areas is one of the major contributors to an increase in flooding. Furthermore, (Warburton et al,. 2012) outlined how the contribution of LULC to flooding depends on the proportional and spatial distribution of various types of LULC within the study area location. The results of this study (Figure 4.1 and 4.2), it shows that the increase of settlement and cultivated land whereas the decrease of forest land, grassland and wetland. Land area under settlement increased by 40.1% of total area during this period. This is due to the increase of population growth that causes the increase in demand of settlement for different commercial and residential purpose. Moreover, this leads to increase the size of settlement areas means an increase in the number of people susceptible to floods due to an increase in the number of inhabitants in the settlement.

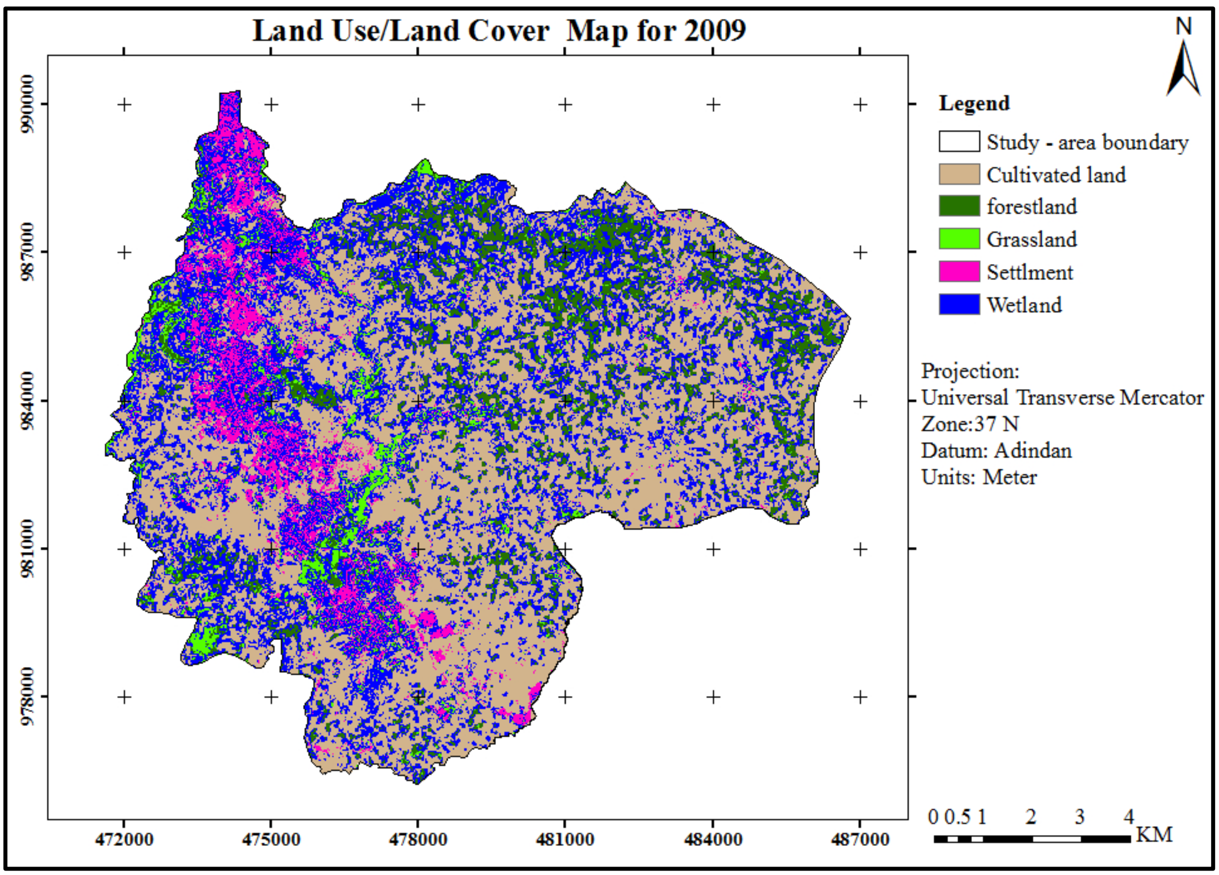


Figure 4. 1. Land Use/Land Cover Classified Map for 2009 Akaki Kality sub-city

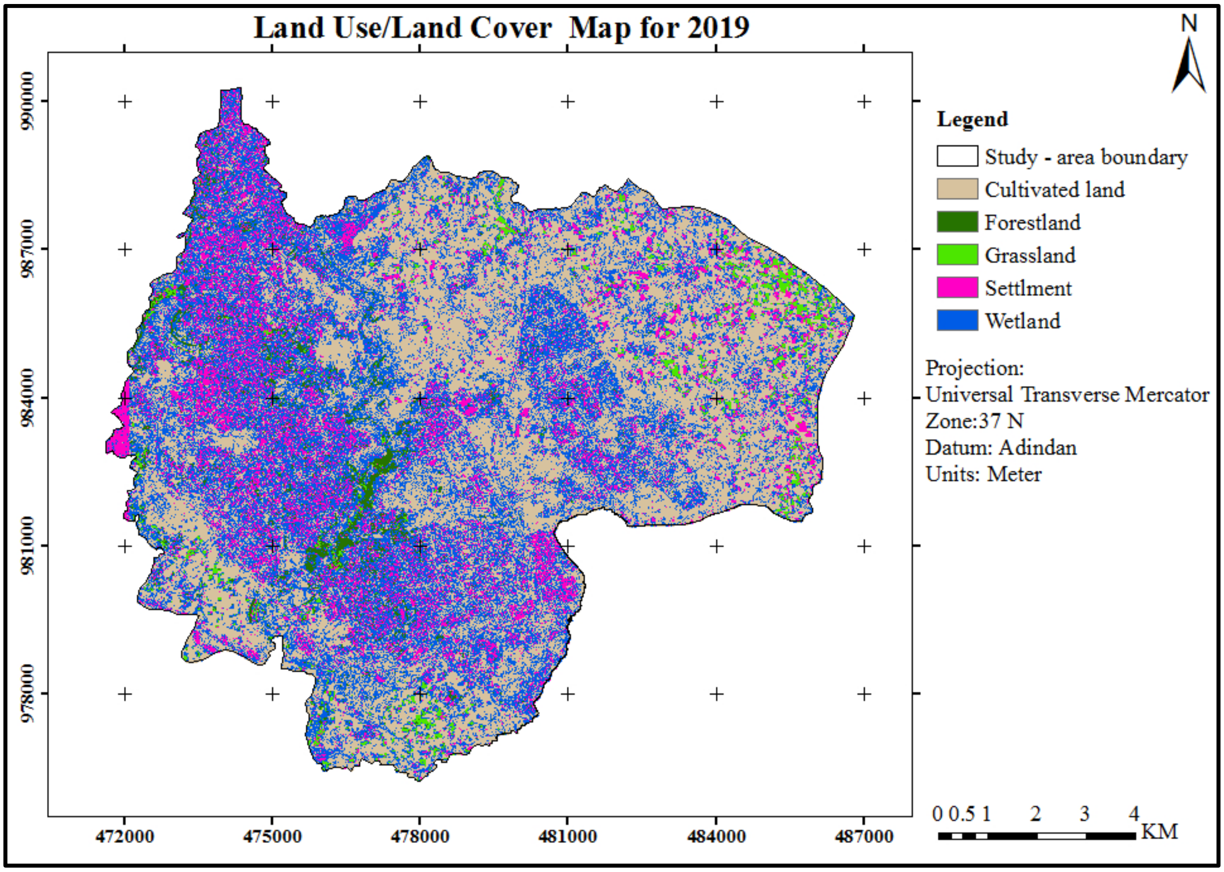


Figure 4. 2. Land Use/Land Cover Classified Map for 2019 Akaki Kality sub-city

Table 4. 1. Land use/Land cover extent for the years 2009 and 2019

LULC Type	2009		2019	
	Area (ha)	% of area	Area (ha)	% of area
Cultivated land	5822.4	47.1	4364.4	35.4
Forest land	1341	10.9	363.3	2.9
Grassland	456.5	3.7	290.1	2.3
Settlement	2282.8	18.5	3197.9	25.9
Wetland	2442.7	19.8	4129.7	33.5

Total	12345.4	100	12345.4	100

The Landsat images were classified generating five major classes; cultivated land, forestlands, grasslands, settlements and wetlands. The distribution extent for the land use/ land cover change for the years 2009 and 2019 as generated through the ERDAS IMAGINE 2015 are as presented in Figure 4.3.

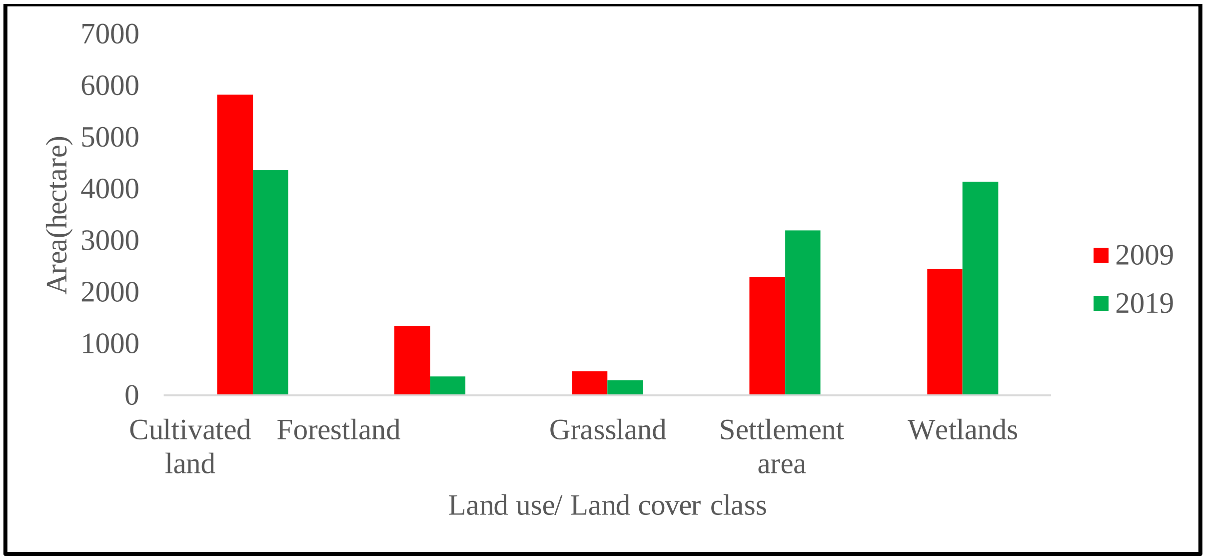


Figure 4. 3. Land Use/ Land Cover Change Extent for 2009 and 2019 Akaki Kality sub-city

From the above Figure 4.3 show that the estimated cultivated lands comprised the largest proportion of the total land use/land cover in 2009 with a total spatial coverage of 5822.4ha (47.1%) while, the estimated grasslands had the least proportion 456.5ha (3.7%). At 2442.7ha (19.8%), wetlands take the second big share of total land use/ land cover in the area. Forestland and settlement area formed a cover 1341ha (10.9%) and 2282.8ha (18.5%) for the total land use/ land cover in the area respectively. Most of the cultivated land are used as cropland areas. The progressive increase in cultivated lands in the period of study was a result of forestland and grassland being cleared/removed. Most of cultivated land found in nearest to streams and marsh areas. Therefore, it indicates that the increase the area of cultivated land people vulnerability to flooding.

In 2009, wetland covered 2442.7 ha of the total land use/ land cover in the study area. In 2019, the size of wetland increases to 4129.7 ha. The increase in the size of the area being inundated with water. The result, indicates that the sub-city was highly risk flooding (Table 4.2).

While, in case of 2019 wetland and settlement area increase spatial to be the highest from land use/ land cover in the area occupying 4129.7 ha and 3197.9 ha respectively. This is due to the increase of population growth that causes the increase in demand of wetland and settlement for different agricultural (i.e, for irrigation purpose people settle near to stream/river), commercial and residential purpose. This leads to increase the size of settlement areas means an increase in the number of people susceptible to floods due to an increase in the number of inhabitants in the settlement. The remaining the decrease the area of cultivated land, forestland and grassland which had spatial extent of 4364.4 ha, 363.3 ha and 290.1 ha respectively. This might be because of the deforestation activities that have taken place for the purpose of urban expansion. In 2019, cultivated land occupied 35.4% of total area which the highest of all land use/ land cover classes. Grassland had the least area coverage at 2.3% in the same years.

4.4.2. Land Use/ Land Cover Change Analysis

The land use/ land cover maps were analyzed for changes in from the years 2009 and 2019. The results of the changes are summarized in Table 4.2. The analysis established that there were either gains or losses within the land use/ land cover classes in the study area (Table 4.2).

Table 4. 2. Change of land use/land cover statistical summary of 2009 and 2019

LULC	2009		2019			
	Area (ha)	% of area	Area (ha)	% of area	change (ha)	change (%)

Cultivated land	5822.4	47.1	4364.4	35.4	-1458	-25.0
Forestland	1341	10.9	363.3	2.9	-977.7	-72.9
Grassland	456.5	3.7	290.1	2.3	-166.4	-36.5
Settlement	2282.8	18.5	3197.9	25.9	915.1	40.1
Wetland	2442.7	19.8	4129.7	33.5	1687	69.1
Total	**12345.4**	**100**	**12345.4**	**100**		

Referring from the above Table 4.2, 2009 Landsat ETM+ as previous stage image whereas, 2019 recent OLI sate stage image the change of each land use/land cover class are describe as follows. During the 10-years period of LULCC observation from 2009-2019 (Table 4.2), LULC was dominated by cultivated land, wetland, settlement area, forestland and grassland. Increase in LULC during this period occurred in settlement area and wetland. Meanwhile, decrease in LULC were recorded in respect of cultivated land, forestland and grassland. For settlement area during this period 2009-2019 the estimated changed in area was an increase of 951.1ha (40.1%), whereas, for wetland the increment was 1687ha (69.1%). Moreover, the estimated decreased in cultivated land, forestland and grassland were in the order of 1458ha (25.0%), 977.7ha (72.9%) and 166.4ha (36.45%) respectively. Forestland decreased by 72.9%. Settlement area has shown the second highest change in terms of area coverage explanation which is highly correlated with population growth. The increase of settlement shows that due to high urbanization cultivated land, forestland and grassland are changed in to building and industries as the most of time manufacturing and industries built up along the stream side to the relation of waste disposal system, this also affected the river, stream and the population along the river side released with other but, not given attention to the protection of flood and the protection of streams and the rivers. Increased size of settlement areas means an increase in the number of people susceptible to floods due to an increase in the number of inhabitants in the settlements. While, an increment of the wetland may be one of the indicators for the prevalence of flooding over years in the area. Because, in 2009 there are different land use/land cover that control the high rainfall and the flow of water like cultivated land, forestland and grassland also contribute the control the flood risk but, in 2019 these land use/land covers are decrease. In the contrary, forestland and grassland shows the highest clearing rate which is directly correlated with surface runoff generation potential. The removal in the area under forestland and grassland increase the chance of flooding in the new land use/land cover classes as there are no filters in form of tree or grass to reduce the flow of storm waters to the lowlands. The decrease of cultivated land the number of built up area increased that means highest change in terms of area urban expansion which is highly correlated with population growth. The decrease of proper cultivated land and removal of forestland and grassland means result of people settle to there in the risk of flooding.

4.4.3. Accuracy Assessment

Accuracy assessment for this study was based on the delineation of the various classes using supervised classification. By creating random/reference points on Arc GIS 10.3 were selected from the classified image and compared against images from online Google Earth (Appendices iv). All the randomly generated points were then identified by the user and assigned in different classes. Error matrices were generated for each year under study area. About 82 training samples (cultivated land: 27, forestland: 10, grassland: 12, settlement areas: 14 and wetland: 19) were selected for land use/land cover class for 2009 (Table 4.3), while about 115 training samples (cultivated land: 11, forestland: 18, grassland: 38, settlement areas: 25 and wetland: 23) were selected in the case of 2019 (Table 4.4). The overall accuracy in the classification was also generated for the years 2009 and 2019 together with the kappa coefficient. The accuracy assessment generated multiple points within the various classes that were either omitted or wrongly placed in different other classes. The accuracy assessment is used to determine the correctness of the classified image. It was performed using confusion matrix. Table 4.3 and 4.4 shows a confusion matrix for the two Landsat images.

Accuracy Assessment of 2009: The land use/land cover map for 2009 year an overall accuracy was 86.6%. The kappa coefficient is an accuracy indicator used in image classification accuracy assessment where near to 0 implies lack of agreement between the ground truth image and the classified image and near to 1 implies complete agreement(Anderson *et al*, 1976). Therefore, the kappa coefficient was 0.83 which complete agreement the classified ground truth image. The results for the various classes are as indicated in the table below. The low accuracy levels for this year were attributed to a rather high level of homogeneity in land cover classes causing high spectral similarities. The images from the year also had a high percentage of cloud cover compared to the images used in 2019.

This led to confusion during classification where many classes were either left out or misplaced in the wrong classes (Table 4.3). The Table shows that the user's accuracy of individual category was from 80% to 92.9%, and the producer's accuracy was from 76.5% to 100%.

Table 4. 3. Error Matrix for 2009

	Reference Data							
Classified 2009 LULC	Class	Cultivated land	Forest land	Grass land	Settlement	Wetland	Total	User accuracy %
	Cultivated land	24	0	1	1	1	27	88.9
	Forest land	1	8	1	0	0	10	80
	Grassland	0	0	11	1	0	12	91.7
	Settlement	1	0	0	13	0	14	92.9
	Wetland	1	0	1	2	15	19	78.9
	Total	27	8	14	17	16	82	
	Producer accuracy %	88.9	100	78.6	76.5	93.8		

Accuracy Assessment of 2019: the overall accuracy attained for the classification on the 2019 image was 90.4%. The kappa coefficient is an accuracy indicator used in image classification accuracy assessment where near to 0 implies lack of agreement between the ground truth image and the classified image and near to 1 implies complete agreement. Therefore, the kappa coefficient was 0.88 which complete agreement the classified ground truth image. Images for the year had a low cloud cover compared to the images used in 2009 and thus an improvement in allocation of the right training sites to the right classes. The classes were also more heterogeneous and it was therefore possible to identify classes more easily. The results of the classification are as indicated in Table 4.4. The Table shows that the user‘s accuracy of individual category was from 81.8% to 97.4%, and the producer‘s accuracy was from 75% to 100%.

Table 4. 4. Error Matrix for 2019

	Reference Data							
Classified 2019 LULC	Class	Cultivated land	Forest land	Grass land	Settlement	Wetland	Total	User accuracy %
	Cultivated land	9	1	0	1	0	11	81.8
	Forest land	1	15	1	1	0	18	83.3
	Grassland	0	0	37	1	0	38	97.4
	Settlement	2	0	1	22	0	25	88
	Wetland	0	1	1	0	21	23	91.3
	Total	12	17	40	25	21	115	
	Producer accuracy %	75	88.2	92.5	91.7	100		

Therefore, it can be concluded that from the above both table the overall accuracy gives the overall results of the confusion matrix. It is calculated by dividing the sum of correct pixels (diagonals) by the sum of pixels in the confusion matrix. As above (Table 4.3 and Table 4.4) the result shows that the overall accuracy of maps increased from 86.6% to 90.4% for the years 2009 and 2019 respectively. According to (Anderson *et al*, 1976), the minimum accuracy value for reliable land use/land cover classification is 85 %. Therefore, the classification carried out in this study produces an overall accuracy that fulfils the minimum accuracy level.

4.3. Factors Governing Flood Vulnerability in the Study Area

The major flood generating factors used for flood risk assessment in are slope, elevation, average rainfall, drainage density, and landuse and soil type. The flood generating raster layers have been classified based on their flooding capacity of the area (Getahun, Y. and Gebre, S. 2015). Flood vulnerability factors particularly in the study area were identified from previous study and literature. According to (Getahun, Y. and Gebre, S. 2015), slope, elevation, drainage density, rainfall, soil type and land use were selected as factors that are important for flood risk assessment in a case study area. The collected data were automated (digitized and clipped by the study area boundary) and organized into logical groupings of the factors. This data sets were collected from various source and processed using geospatial technology. Therefore, the following flood factor developed for under mentioned are the factors selected for flood vulnerability map in Akaki Kality sub-city.

4.3.1. Drainage Density Factor

Drainage system is related to the nature of soil and properties. Areas with high drainage density are highly susceptible to erosion and result to massive sedimentation on the lower grounds. Areas with high drainage densities are considered to be well drained and are characterized with a highly permeable rock structure and therefore low in flood risk. Areas with high drainage densities are considered to be less drained and characterized with susceptible to flooding (Ouma, O. and Tateishi, R. 2014). Drainage network of the study area were digitized from 1:50000 Topographic Maps. And using the spatial analyst, line density module was used to compute drainage density of the area. Density is calculated in units of length of stream lines per unit of area. The drainage density layer was further reclassified in five sub groups using natural breaks (Jenks)classification schemes. Analysis of drainage density in the area indicated that the density ranged between 0 to 20.44 km/km^2(Table 4.5). The maps and reclassified are presented in Figure 4.4 and Table 4.5, respectively.

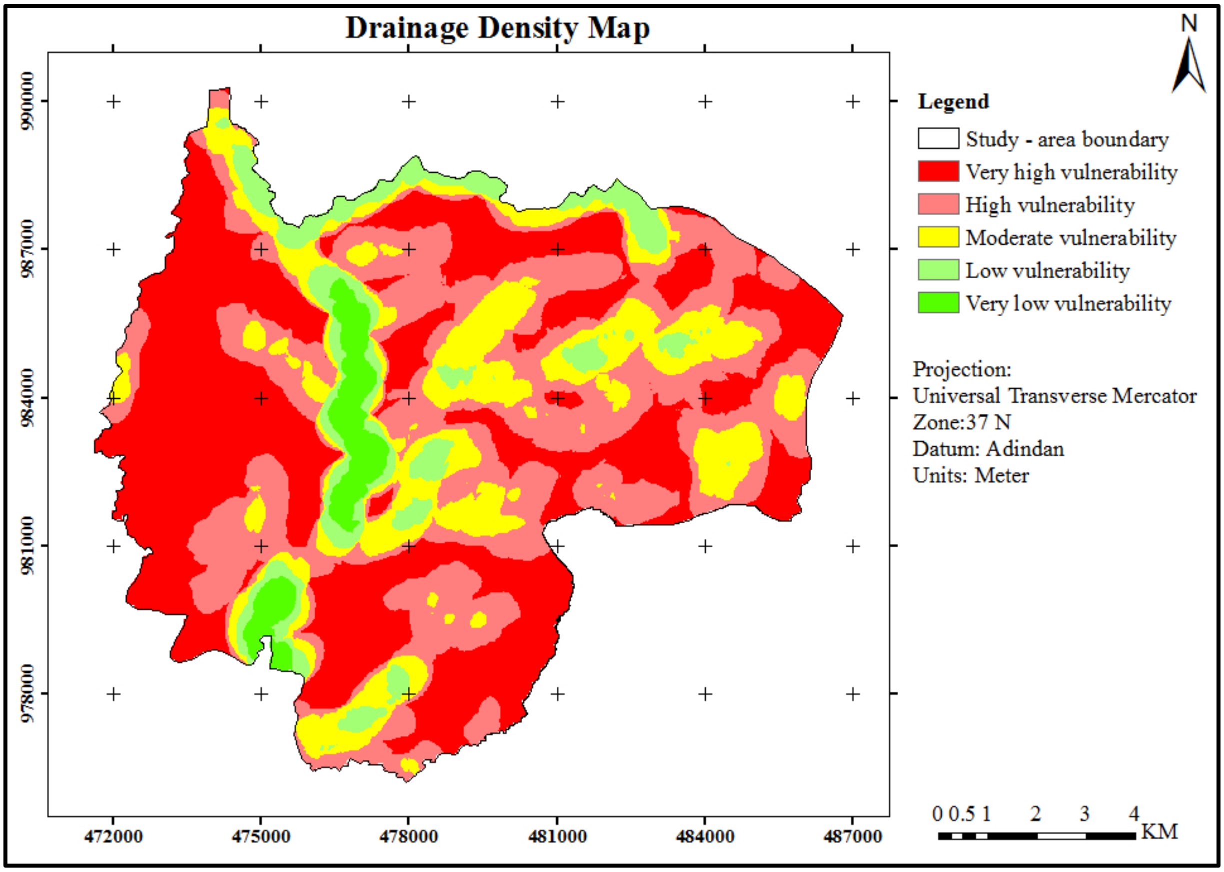


Figure 4. 4. Reclassified Drainage Density Map of Akaki Kality Sub-city

Table 4. 5. Reclassified drainage density data

Drainage Density (km/km^2)	Ranking	Area(ha)	% of area	level of flood vulnerability
0-1.60	5	5017.16	40.6	Very high
1.60-3.93	4	3912.24	31.7	High
3.93-6.65	3	2073.78	16.8	Moderate
6.65- 11.06	2	910.56	7.4	Low
11.06- 20.44	1	431.66	3.5	Very low
Total		**12345.4**	**100**	

From the above Table the largest area was covered 40.6% of very high vulnerability, whereas 31.7%, 16.8 %, 7.4% and 3.5% area are covered high, moderate, low and very low flood vulnerability respectively.

4.3.2. Slope Factor

Slope plays a major role in flood risk mapping (Alemayehu, Z. 2007). Flat surfaces that don't permit fast flow of surface runoff are at more risk as they are vulnerable to flooding compared to the steep areas that allow fast flow of storm water (Ouma, O. and Tateishi, R. 2014). The classes of slope with lesser values were allocated higher vulnerability as their angles are not steep. Classes with the highest slope values were assigned lower vulnerability for flooding values. The slope of the Akaki Kality Sub-city is derived from a 5-meter contour interval feature class which is digitized from topographic map of 1:50,000 scale and further rectified in GIS environment. This feature was converted to 3d shape file using 3D Analyst in convert facture to 3D module by interpolating contour using an attribute as a source. Further TIN was created using 3D Analyst in Create TIN from feature 3D Analyst in create was created using 3D Analyst in create TIN form feature (3D shape). The slope facture class was further converted to raster using conversion tool in To Raster/ Feature to Raster module. The slope raster layer was further reclassified in five sub group using Arc GIS software, Spatial Analysis Tool, Surface Analysis, and Slope. The slope raster layer, which was reclassified in five sub-group using natural breaks (Jenks) classification schemes. The generated classes were then ranked depending on their influence on flooding. The lowest rank was assigned to the very steep slope because they result to low infiltration and high surface runoff thus less likelihood of flooding. The low slope areas were ranked highly due to their ability to hold water thus making an area more susceptible to flooding. The slope map in the study area ranges from 0 to 50.7 degree. The maps and reclassified are presented in Figure 4.5 and Table 4.6, respectively.

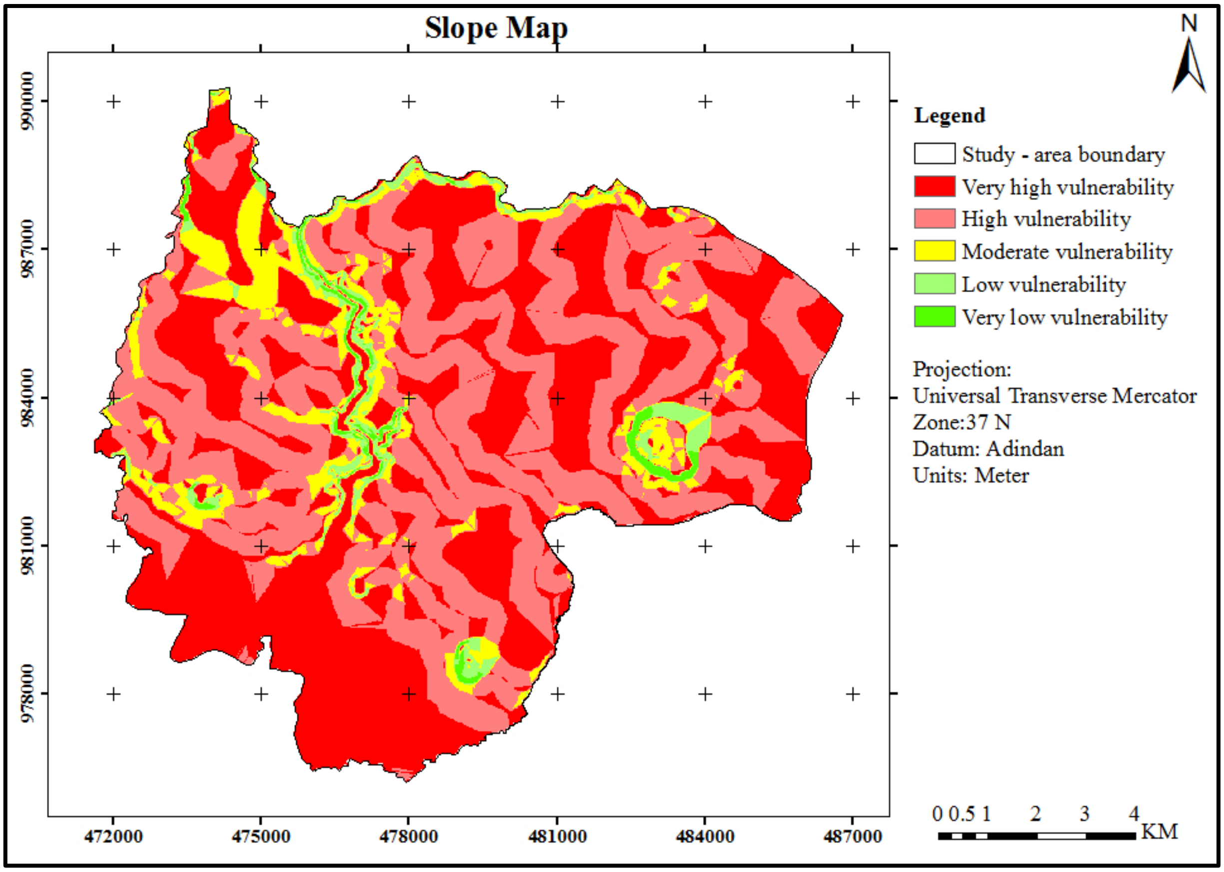


Figure 4. 5. Reclassified Slope Map of Akaki Kality Sub-city

Table 4. 6. Reclassified slope data

Slope (degree)	Ranking	Area(ha)	% of area	level of flood vulnerability
0-1.6	5	5271.80	42.7	Very high
1.6-5.8	4	5491.76	44.4	High
5.8-10.1	3	1080.60	8.8	Moderate
10.1-20.5	2	362.32	3.0	Low
20.5-47.7	1	138.92	1.1	Very low
Total		**12345.4**	**100**	

From the above Table 4.6 shows that largest land area 44.4%, and 42.7%(gentle slope) respectively subjected to high and very high flood vulnerability respectively. The results obtained from slope totally shows that as the Sub-city was built on gentle slope to contributing flood hazard. And the reaming 8.8%, 3.0% and 1.1 % (very steep slope) of land area subjected to moderate, low and very low flood vulnerability respectively. Therefore, the highest slope value with fewer floods and the least with high probability to be hit by flooding.

4.3.3. Elevation Factor

All the processes for the development of the elevation factor are as explained above in the slope factor development. The lower the elevation, the higher will be its vulnerability to flooding (Woubet, G. and Dagnachew, L.2014). The elevation of the Akaki Kality Sub-city was derived from 5-meter interval contour feature class which is digitized from the Topographic Map 1: 50,000 scale and further rectified in ArcGIS environment. This feature was converted to 3D shape file using 3D Analyst in Convert feature to 3D module by interpolating contour using an attribute as a source. Further TIN was created using 3D Analyst in Create TIN from Feature (3D shape). Elevation raster layer was derived from the created TIN. The elevation raster layer was further reclassified in five sub groups using Arc GIS software, Spatial Analysis Tool and Natural Breaks (Jet) classification schemes based on topography the terrain, past flood risk. And new values were reclassified according to flood vulnerability. The maps and reclassified are presented in Figure 4.6 and Table 4.7, respectively.

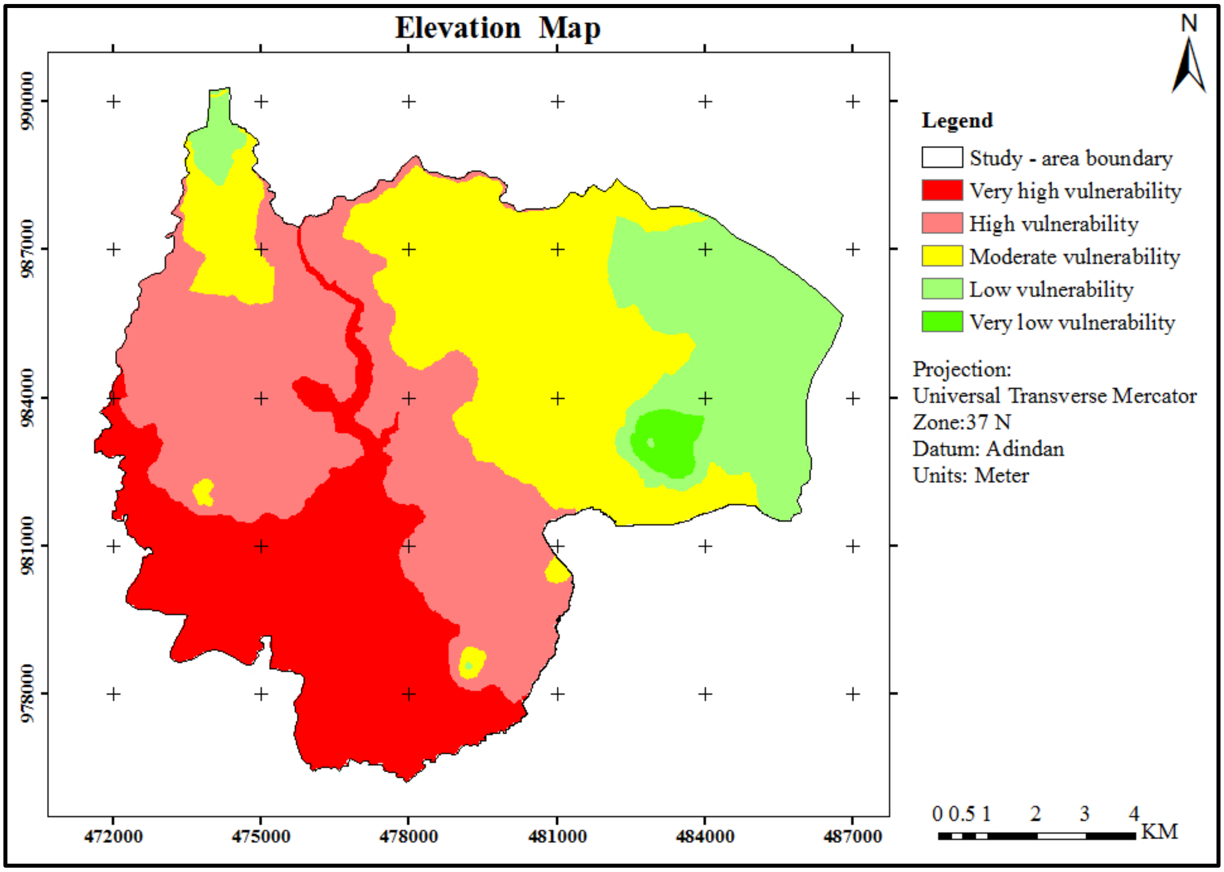


Figure 4. 6. Reclassified Elevation Map of Akaki Kality Sub-city

Table 4. 7. Reclassified elevation data

Elevation(m)	Ranking	Area(ha)	% of area	level of flood vulnerability
2060-2108	5	3121.92	24.5	Very high
2108-2164	4	3887.16	31.5	High
2164-2207	3	3459.88	28.0	Moderate
2207-2249	2	1824.84	14.8	Low
2249-2340	1	151.60	1.2	Very low
Total		**12345.4**	**100**	

From the above Table 4.7 indicated that the highest area (31.5%) subjected to the high flood vulnerability, whereas 28.0%, 24.5%, 14.8% and 1.2 % respectively covered the Sub-city was subjected to moderate, very high, low and very low flood vulnerability. In this classification process an area at lowest elevation is strongly affected by flood and hence ranked to 5 while an area at relatively higher elevation is the least to be affected by flood and hence ranked to 1.

4.3.4. Rainfall Factor

Heavy rainfall is the major cause of floods. Floods occur mainly in areas of heavy rainfall when available drainage systems are unable to convey excess water to the flood plains or water bodies. Amount of runoff is related to the amount of rainfall experienced in an area. In cases of heavy rainfall, water level rises above river banks, dams or lakes and starts overflowing leading to flooding (KRCS, 2013).

Rainfall data Akaki and Kality stations 15 years i.e from 2005 to 2019 collected from National Meteorological Agency (NMA). The data were recorded for the months of the year; since that in order to find estimate intense rainfall, the average maximum monthly rainfall data from each year from 2005 to 2019, both station (Appendix i) were identified and sum up, their average was computed and divided by fifteen year to obtain Average Maximum Monthly (AMM) rainfall of the two stations.

Spatial distribution of rainfall was generated using average maximum monthly rainfall. The data was already interpolated from the point data using the Inverse Distance Weighting (IDW). IDW interpolation determines cell values using a linearly weighted combination of a set of sample points. According to (KRCS, 2013) the interpolated surface was converted to raster layer, the interpolated rainfall classes were then reclassified and ranked based on their further reclassified in five sub groups using natural breaks (Jenks) classification schemes influence on flood vulnerability. Areas with the highest average monthly rainfall are considered to be more at risk of flooding than areas with the least rainfall. From the rainfall map, areas near the Southern area of the boundary receive the highest rainfall amounts. Therefore, it follows that the settlement areas there in have flat terrain rainfall and types of soil that are less permeable; there is a likelihood of them being flooded after precipitation events. The maps and reclassified are presented in Figure 4.7 and Table 4.8, respectively.

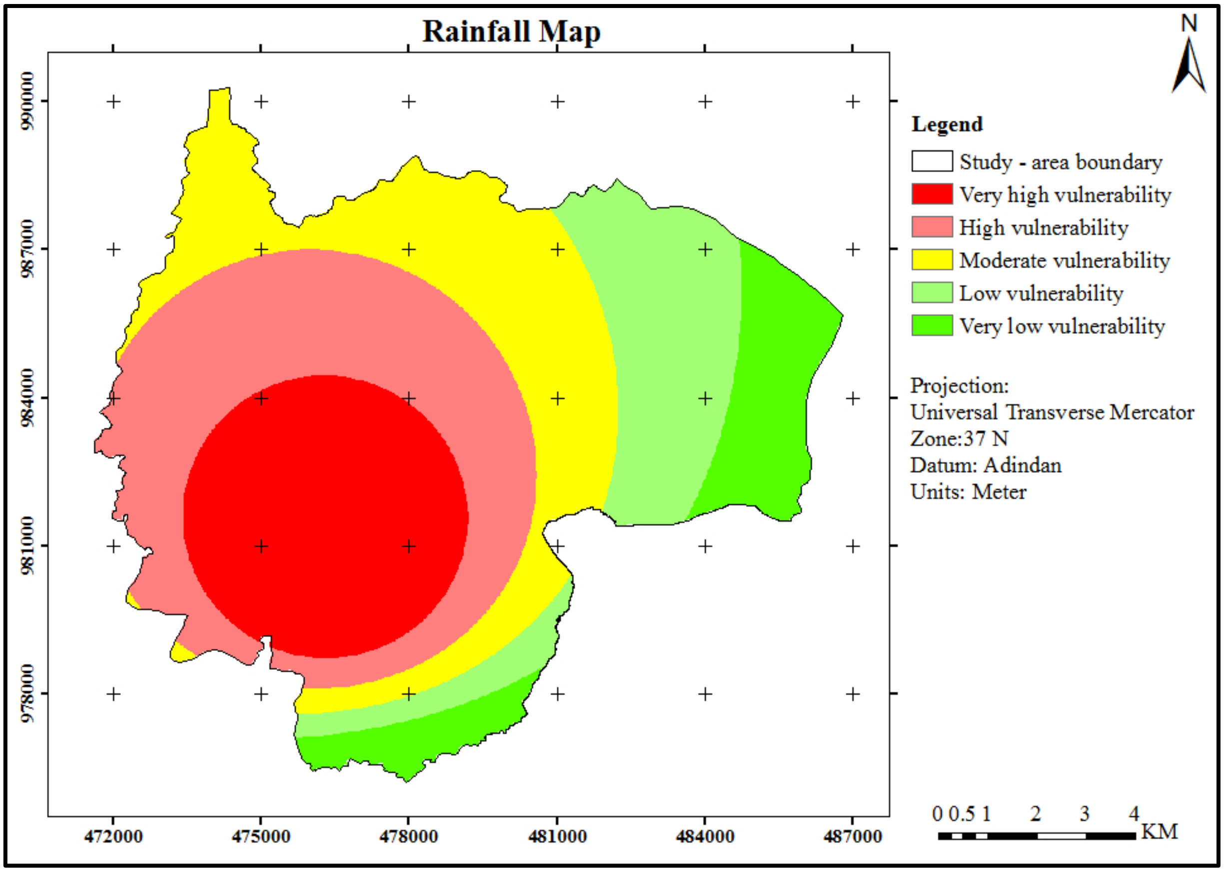


Figure 4. 7. Reclassified Average Maximum Monthly Rainfall Map of Akaki Kality Sub-city for 15 years

Table 4. 8. Reclassified rainfall data

Average Maximum Monthly rainfall (mm)	Ranking	Area(ha)	% of area	level of flood vulnerability
249.17-250.92	1	1291.20	10.4	Very low
250.92-252.70	2	2014.20	16.3	Low
252.70-254.47	3	2984.96	24.3	Moderate
254.47-256.23	4	3458.32	28.0	High
256.23-258.00	5	2596.72	21.0	Very high
Total		**12345.4**	**100**	

From the above Table the total area of 28.0% subjected to high flood vulnerability area covered the remaining 10.4%, 16.3%, 24.3% and 21.0% are low, very low, moderate and very high flood vulnerability area covered. This is not to mean that there was this many differences between different places of the Sub-city. In the reclassification process an area with higher rainfall, is very highly affected by flood and then ranked as class 5. Whereas high vulnerability class, there is a class high ranked as class 4, moderate ranked as class 3, low ranked as class 2 and very low ranked as class 1.

4.3.5. Soil Factor

Soil type and distribution is a major factor controlling the quantity of surface water occurrence. Various soil types have the capacity to influence infiltration differently. The major soil types in the area were identified and reclassified based on their influence on flood risk. The area was found to Eutric Vertosols. Areas falling within Eutric Vertosols a kind of clay soils was ranked highly at flood risk as they have poor porosity and are less permeable (Tadesse, D. and Haile, D.2016). The soil type was collected from the Ministry of Agriculture. Eutric Vertosols has only one categories of soil types was covered from the total study area. Right after updating, soil type shape file was converted to raster layer using Conversion Tools/ Feature to Raster. Then further the data layer was reclassified based on their water infiltration capacity into fiver sub groups which are classified using natural breaks (Jenks) classification schemes. These help in determining the ability of the soil to absorb water. Floods occur in areas where soils have low infiltration capacity as this generates more surface runoff. The maps and reclassified are presented in Figure 4.8 and Table 4.9, respectively.

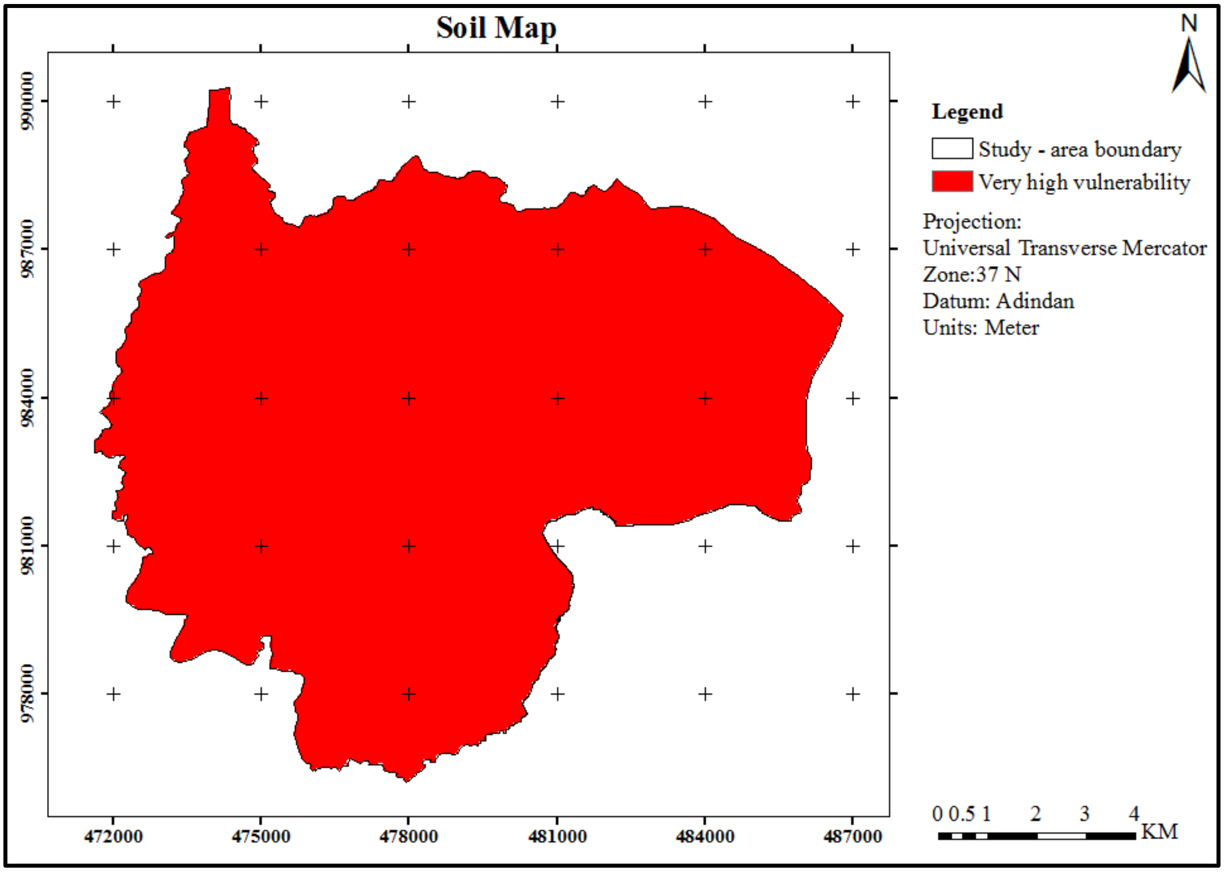


Figure 4. 8. Reclassified Soil Map Akaki Kality Sub-city

Table 4. 9. Reclassified soil type data

Soil type	Ranking	Area (ha)	% of area	level of flood vulnerability
Eutric Vertosols	5	12345.4	100	very high
Total		**12345.4**	**100**	

From the above Table shows Eutric Vertosols the whole coverage area soils type the in the study area. This soil type that has a very high capacity to generate a very high flood rate is ranked as class 5 because, low water available capacity, heavy rainfall, low permeability and porosity when wet, leading to low infiltration rate which indicates that the amount of runoff generation and vulnerability to flood hazards.

4.3.6. Land Use/Land Cover Factor

Land cover and land use play a crucial part in water percolation, infiltration and ground water recharge; parameters which are important while assessing flood risk. Land use/land cover is an important and a predominant aspect in assessing an area's susceptibility to flood risk. This is because the land use/land cover characteristics not only affect the use into which land is put into, but also its influence with respect to soil infiltration and soil stability (Okoth, D. 2010).

The land use/land cover distribution map for 2018 the study area was directly obtained from Ethiopian Geospatial Information Agency (EGIA), SPOT 1.5 m satellite images which freely offers the Landsat Orthorectified data collection which consists of a global set of high-quality, marketing the high-resolution images. The maximum likelihood supervised classification method was adopted using ERDAS Imagine 15 software and later analyzed using ArcGIS spatial analyst tools as shown in Figure 4.9. The land use/land cover pattern of the study area has been classified into five categories based on the influence on flood risk and the exposure of humans to risk. These were settlements, wetlands, forestlands, grasslands and cultivated land. Habitation areas are more likely to be found in areas categorized as settlements while habitation is least likely to be on the forestland areas. In many cases, constructed drainage lines and culverts in the urban areas are usually too small to accommodate storm water which causes water to overflow on the roads and pavements after precipitation events. The problem is compounded by huge amounts of poorly disposed solid waste which clogs the drainage systems. Land use/land cover characteristics activities therefore only compound on the flood risk posed by a soil's infiltration capacity, the nature of slope on which land use activities are conducted or the geology of the areas under each LULC category as it influences on the drainage system. Changes in land use and land cover; especially the removal of vegetation increases an area's chances to flooding (Woubet, G. and Dagnachew, L.2011).

Accordingly, settlement was given more weight, which was equal to 5, wetland was given weight 4, and cultivated land was given weight of 3, forestland was given weight 1, and grassland was given weight of 2. The maps and reclassified are presented in Figure 4.9 and Table 4.10, respectively.

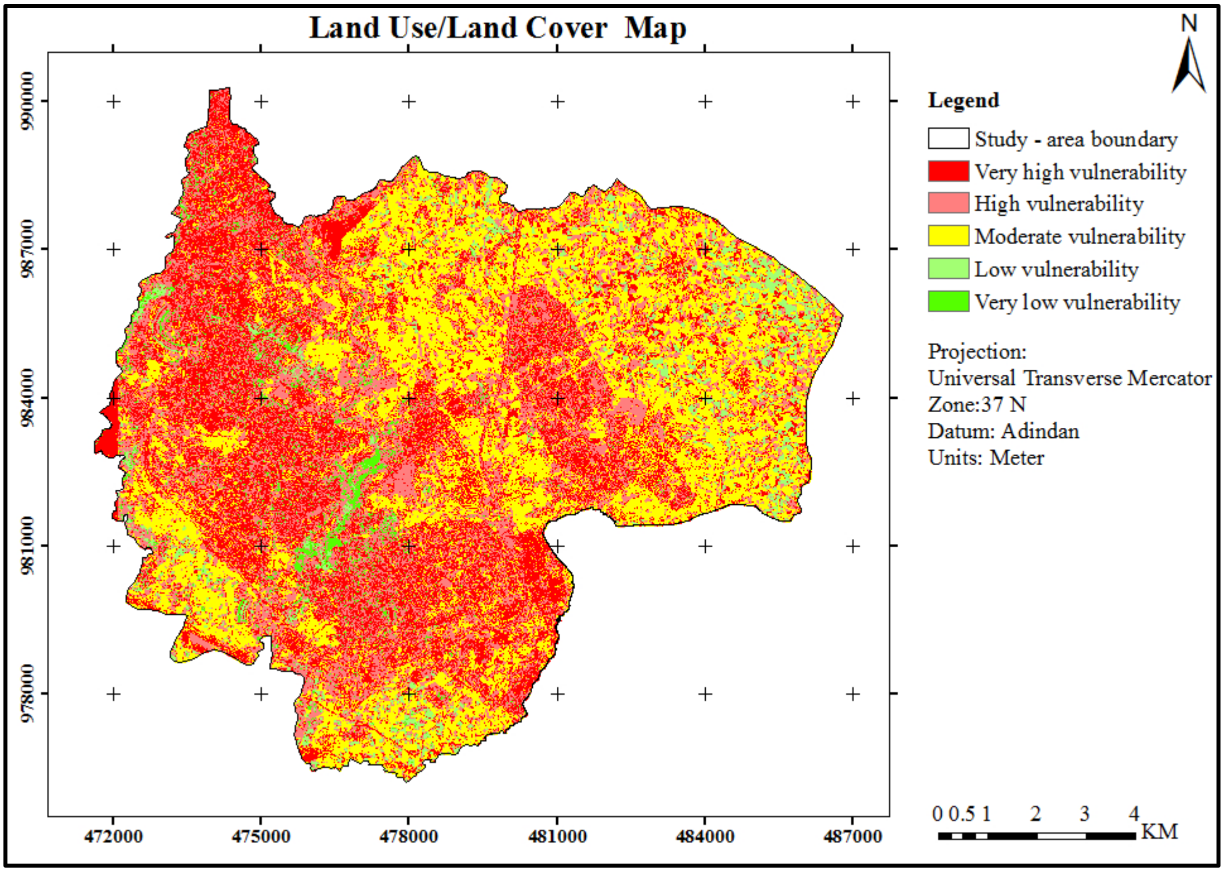


Figure 4. 9. Reclassified Land Use Layer Map Akaki Kality Sub-city

Table 4. 10. Reclassified land use type data

LULC type	Ranking	Area (ha)	% of area	level of flood vulnerability
Settlement	5	4017.74	32.5	Very high
Wetland	4	3258.08	26.4	High
Cultivated land	3	4257.92	34.5	Moderate
Grassland	2	520.90	4.2	Low
Forestland	1	290.76	2.4	Very low
Total		**12345.4**	**100**	

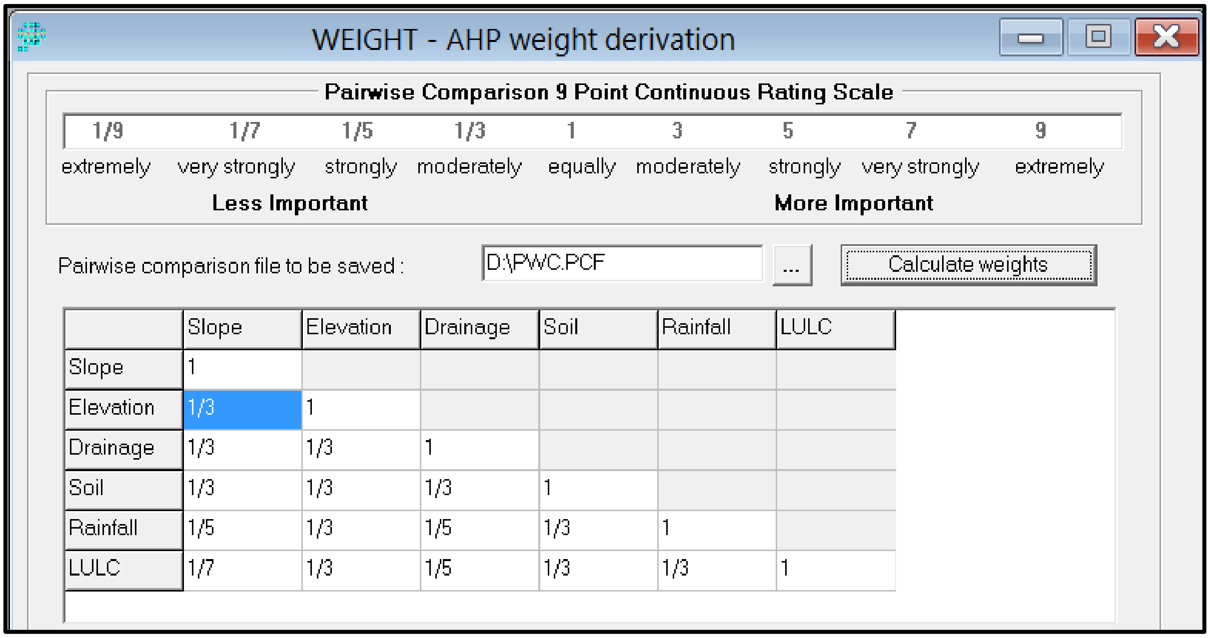
From the above Table the total area of 32.5% subjected to settlement were very high flood vulnerability area covered because, Settlements were given the highest rank due to human interference with soil structure and infiltration capacity of soils through vegetation removal, urbanization and cultivation whereas, 26.4%, 34.5%,4.2% and 2.4% subjected to high, moderate, low and very low flood vulnerability respectively.

4.4. Weighted Overlay Analysis

Flood risk analysis was computed by Weighted Sum Overlay of slope, elevation, drainage density, rainfall, land use and soil developed factors. The IDRISI 32 software was used to factors, such as slope, elevation, rainfall, drainage density, land use, and soil type in the Awash River basin using GIS along with multi-criteria AHP techniques and a weighted overlay (Getahun, Y. and Gebre, S. 2015).

In this study flood risk analysis was computed by weighted overlay of slope, elevation, drainage density, average monthly rainfall, land use and soil type developed factors. The weights for each factor were given previous studies and based on literature.

In the case study, all thematic layers were integrated in ArcGIS 10.3 platform to create a map depicting five flood risk zones. Accordingly; the Eigen Vector of the weight of the factor was computed in IDRISI 32 Software in Analysis menu of the decision support/weight module based on the given pair-wise comparison (Figure 4.10). The weighted module was fed with the pair wise comparison 9-point continuous scale. Then the principal Eigen Vector of the pair wise comparison matrix using the factors affecting flood risk was calculated. A consistency ratio values less than 0.1 is acceptable. The consistency ratio of the calculated Eigen Vector was 0.09 (Figure4.8) that shows that the given pair-wise weights are accepted. The pair-wise comparison indicated a high weight for the slope followed by the elevation, drainage density, soil rainfall and land use presented (Table 4.11). The input layers were obtained from the following thematic maps: drainage density, slope, elevation, rainfall, soil and landuse. Those layers obtained from the reclassified: drainage density, slope, elevation, rainfall, soil and landuse were added together by overlaying all the thematic layers using the Weighted Overlay method with the help of the spatial analysis tool in ArcGIS 10.3 to generate a flood risk map.



	Slope	Elevation	Drainage	Soil	Rainfall	LULC
Slope	1					
Elevation	1/3	1				
Drainage	1/3	1/3	1			
Soil	1/3	1/3	1/3	1		
Rainfall	1/5	1/3	1/5	1/3	1	
LULC	1/7	1/3	1/5	1/3	1/3	1

Figure 4. 10. Pairwise matrix of flood developed factors

The principal eigenvector of the pair wise comparison matrix flood developed factors was calculated as follows:

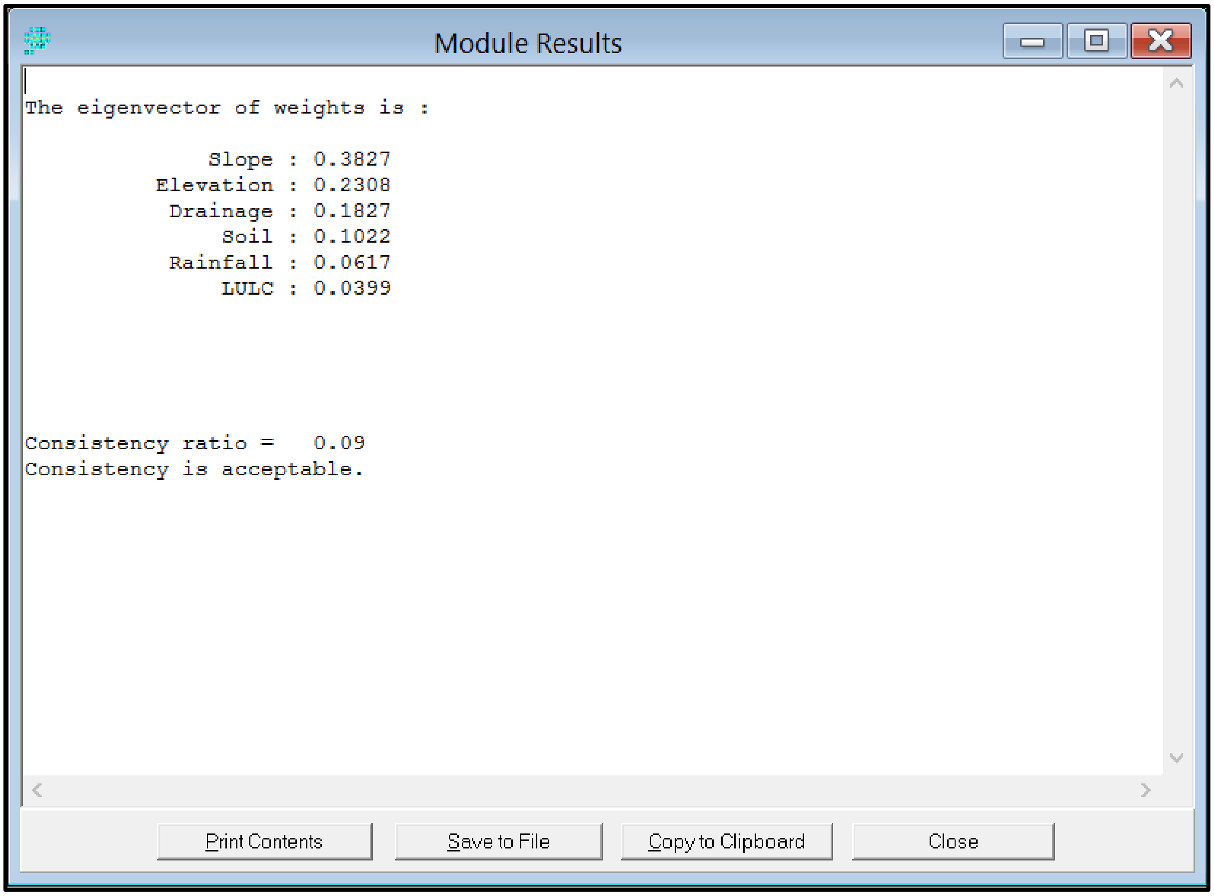


Figure 4. 11. Eigenvector of the pair wise comparison matrix

Table 4. 11. The Eigen vector weights of each flood developed factors

S/No	Selected Factors	Weights
1	Slope	0.3827
2	Elevation	0.2308
3	Drainage density	0.1827
4	Soil	0.1022
5	Rainfall	0.0617
6	LULC	0.0399
Total		**1**

4.5. Flood Risk Analysis

Flood risk map was generated by overlaying/combining reclassified information based on the landuse type, slope, elevation, drainage density, and soil type and rainfall distribution. The various datasets (drainage density, landuse, soil and rainfall) were converted into raster formats using the image analysis commands in ArcMap (Yirga, K.2016). They were then reclassified under the Spatial Analyst Tool and values assigned with a rating scale of 1 to 5 based on their influence on human susceptibility. The output was a flood risk map with five risk areas namely; very high, high, moderate, low and very low (Figure 4.12). The very low risk areas seemed to be negligible as the overlay procedure did not recognize or generate them. All the layers from different datasets were then assigned weights based on their influence on risk posed to humans, overland flow and water percolation after precipitation events and overlain to produce the flood risk. The map output demonstrates that, the study area is dominated by high flood and moderate risk zone which covers the largest area. Very high-risk zones are concentrated in the Southern side of the area. Most of the areas in the settlements and the urban agriculture within the high-risk zones. But grassland and forestland are within moderate and low risk zones.

The flood risk map depicts the concern, the environment formation and the population's vulnerability in the areas that are prone to the hazard; thus the risk map takes into account, of human settlement areas and infrastructure area like towns, roads, rivers, and the cultivated areas. Land use changes increase the susceptibility of an area to the risk of flooding. The land use maps, figures and percent changes all inform different forms of conversions and modifications. This includes reduction in the extent of vegetation cover in the area which in turn exposes the area to increased surface runoff and possible overflow of low lying areas where most settlement areas are located. The flood risk maps and reclassified are presented in Figure 4.12 and Table 4.12, respectively.

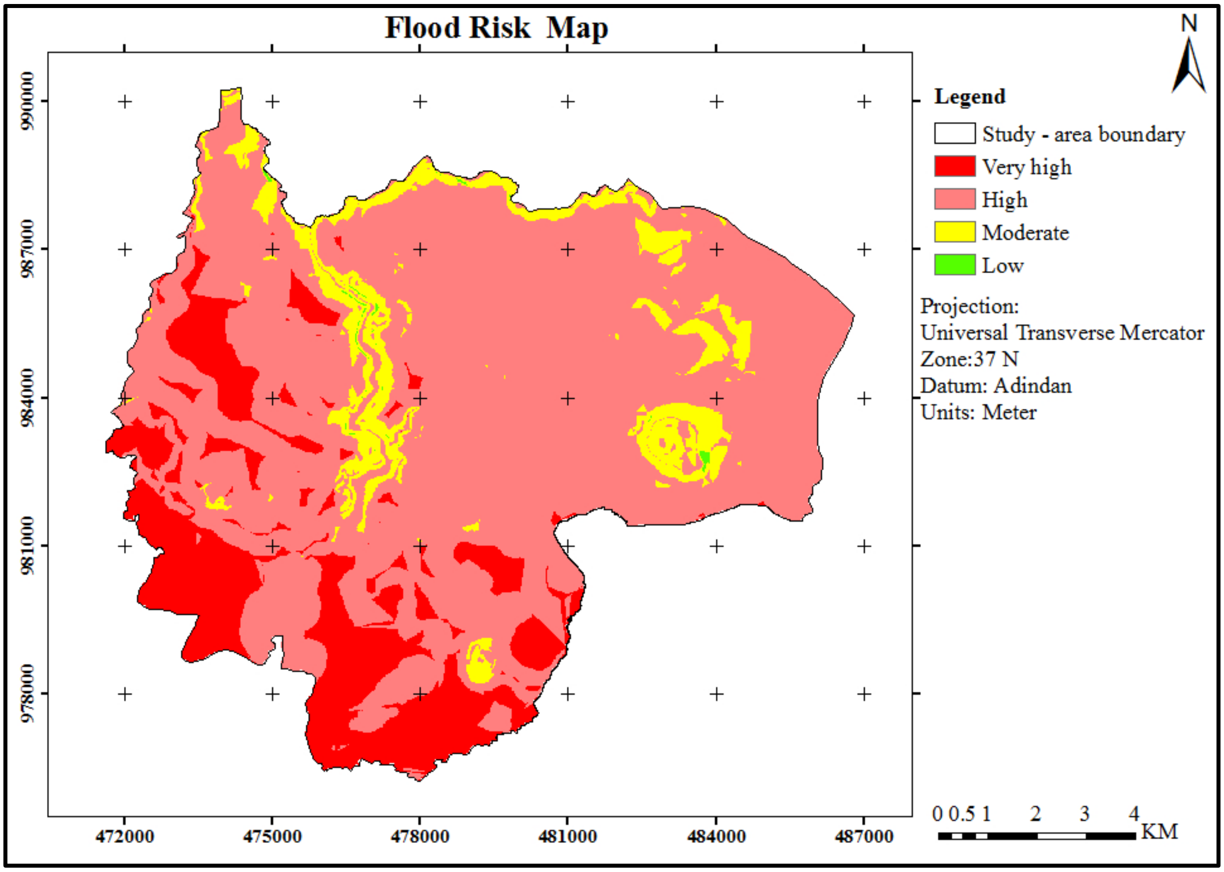


Figure 4. 12. Flood Risk Map of Akaki Kality Sub-city

Table 4. 12. Flood risk category and area of coverage

Ranking	Area (ha)	% of area	Flood risk category
5	2189.64	17.7	Very high
4	9057.24	73.4	High
3	1068.32	8.7	Moderate
2	30.2	0.2	Low
1	0	0	Very low
Total	**12345.4**	**100**	

From the above Table flood risk map shows that 2189.64, 9057.24, 1068.32 and 30.2 hectare were corresponding to very high, high, moderate and low flood risk, respectively (Table 4.12). The risk map indicates that very high flood risk 17.7% threats are in Akaki River the downstream part of peripheries which covered settlement and built up area. This part contains substantial amount of alluvium deposits and flat surface, which hazard flooding. The high flood risk covers the largest area, which is 73.4% from the total area covered and South Western part of the study area was the most risk to flooding in the above Figure 4.12. Whereas, moderate 8.7% and low 0.2% flood risk are covered in the North West and Central peripheries respectively. Whereas no area of the sub-city subjected to very low flood risk.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

This study endeavored to identify areas in Akaki Kality sub city that are susceptible to flooding and generate a geospatial technology-based flood risk map. Satellite images were considered to be a great significance factors for land use/land cover change studies with contribution for flood risk in the study area. In the same manner, a total of five land use/land cover classes were identified and extracted from the Landsat images as the major land use/land cover classes in the area. They are cultivated land, forestlands, grasslands, settlements and wetlands. The spatial distribution and analysis of LULC changes during the period 2009-2019 have an increased in some LULC classes that have the potential to reduce recharge areas and also contribute to flooding in the study area. This were, cultivated land, changed (decrease) by 25.0% from 2009 to 2019, whereas wetland increased by 69.1% during the indicated period. Moreover, an increment of wetland may be one of the indicators for the prevalence of flooding over ten years in the study area. Because of this, in 2009 there are different land use/land cover that control high rainfall and the fall of water like forestland and grassland also contribute to control flood risk but, in 2019 these land use/ land covers were decrease. Whereas, forestland and grassland decreased by 72.9% and 36.45% respectively, between this period, while settlement increased by 40.1%. Meanwhile, vegetated area including forestland and grasslands; which were critical for mitigating the effect of flooding, have declined over time to the detriment of cultivated land and settlement areas. Via the assessment of the classification were then assessed for quality through determination of the classification accuracy for the years, the classified images were then analyzed for consistency. For the years 2009 and 2019, the overall accuracy increased from 85.4 percent to 90.4 percent respectively.

Hence, in this study pairwise comparison method integrated with GIS and MCE techniques were delineated flood risk map. However, the result of this map was designed as very high, high, moderate, low and very low on the output map depicting the level of flood risk of the study area. In the same way, the result obtained on flood risk map consisted low, moderate, high and very high flood risk, which depicts that there are no subjected to very low flood risk in the study area.

In summary, the delineated flood risk map result indicated that 9057.24 ha (73.4%) total area of sub-city was subjected to high flood risk zones coverage, while 2189.64ha (17.7%), 1068.32 (8.7%) and 30.2ha (0.2%) area of the sub-city subjected to very high, moderate, and low flood risk zone area coverage of the sub-city respectively. To conclude that, the delineated map of case the study indicated that, the Southern and the South Western part of the study area is the most vulnerable to flooding. This part contains substantial amount of alluvium deposits and a flat surface, which hazard of flooding.

5.2. Recommendation

Based on the result of the present study, the following recommendations are suggested for decision makers to minimize the flood risk of the case study and future researchers:

- ✓ The main focus of this study was conducted on Akaki Kality Sub-city. However, for further research work is needed to cover the whole Addis Abeba City Administration by identified flooding risk hotspot area covering.
- ✓ For future work stakeholders must be create a web-based Geographic Information Systems (GIS) application, easy to use interface we develop allow non-GIS experts, which would help to people living in flood plains, who may at one point be vulnerable due to their proximity to the river and the amplitude of the flooding.
- ✓ The Akaki Kality sub-city Land Administration Office should be controlling their improper settlement along the river side by using Geospatial Technology map out(extract) the flooded areas which shows levels of flood risk and prioritization for flood zones.
- ✓ Hospitals, industries and different factories should control the solid and liquid waste (like, oil, chemical, domestic waste etc..) disposal systems and organizing the community with solid waste control and disposal offices and managing hazardous and toilet wastes that are discharged directly in to the river and regulate their waste all round.
- ✓ The sub-city was lack of awareness compliance of appropriate buffer zone for implementation of house construct near the to streams. Therefore, in order to mitigate flood hazard, the stakeholder should be awareness house built near to stream selecting appropriate(standard) buffer zones.

REFERENCES

AACFEPRA. (2018). Eighty three perished in fire, floods yea*r*. Addis Abeba: Addis Abeba City resilience project.

Anderson, J. Hardy, E. Roach, J. and Witmer, R. (1976). A Land Use and Land Cover Classification System for use with Remote Sensor Data. *Geological Survey Professional Paper 964* , 1-28.

Ayenew, E.(2017). Spatio-temporal Assessment of Land use and Land cover change and its impact on Akaki -Kality Sub City Addis Ababa, “Unpublished” Thesis Submitted to Addis Abeba University, 21-24.

Balabanova, S. and Vassilev, V. (2010). Creation of flood hazard maps”, BALWOIS 2010 Ohrid, Republic of Macedonia. International Journal of Water Resources and Environmental Engineering, 68-72.

Berz, G. W. Kron, T. Loster, E. Rauch, J. Schimetschek, J. Schmieder, A. Siebert,A. Smolka and Wirtz, A. (2001). World map of natural hazards: A global view of stribution and intensity of significant exposures. Natatural Hazards, 443-465.

Birhanu, A. Masih, I. van der zaag, P. Nyssen, J. Cai X. (2019). Impacts of land use and land cover changes on hydrology of the Gumara catchmen*t*. Ethiopia: Physics and Chemistry of the Earth.

Bosch, J.M. and Hewlett, J.D. (1982). A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology, 3–23.

Bronstert, A. (2003). Floods and climate change: Interactions and impacts. Risk Anal, 23(3), 545-557.

Christensen, H.J. and Christensen, B.O. (2003). Climate modelling: Severe summertime flooding in Europe. Nature, 421, 805-806.

Congalton, R. (1991). A Review of assessing the accuracy of classifications of remote sensing data. Remote Sensing of Environment, 35-45.

CSA. (2013). Population Projection of Ethiopia for all Regions, at Werda level from 2014-2019. Addis Abeba: Federal Democratic Republic of Ethiopa, Centeral Staatistical Agency.

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

Eastman, J.R. (2001). IDRISI Guide to GIS and Image Processing. Clark: Clark University Version 32.20.

Eastman, R.J. (2006). IDRISI Andes: Guide to GIS and image processing Worcester, MA. Clark Labs, Clark University: USA.

Enyew, B and Steeneveld, G. (2014). Analysing the impact of topography on precipitation and flooding on the Ethiopian highlands. Journal of Geology & Geosciences, 2329-6755.

European Commision. (2001). Manual of concepts on land cover and land use nformation systems (2000 ed.). Luxembourg: European Commision.

European Commission. (2007). Directive 2007/60/EC of the European and Parliament and of the Council of 23 October, 2007 on the assessment management of flood risks. Official Journal of the European Union, 27-34.

Fanuel, S. (2007). Aquifer Characterization of Addis Ababa. School of graduate studies, Unpublished" Thesis Submitted to Addis Abeba University,25-40.

Feyera, A. (2007). Modeling on Akaki Rivers Liquid Waste Disposal and Base flow Separation, "Unpublished" Thesis Submitted to Addis Abeba University,23-34.

Feyissa, G. Zeleke, G. Gebremariam, E. and Bewket, W. (2018). GIS based quantification and mapping of climate change vulnerability hotspots in Addis Ababa. Geoenvironmental Disaster, 1-17.

Fu Q., Shi R., Li T., Sun Y., Liu D., Cui S., Hou R. (2019). Effects of land-use change and climate variability on streamflow in the Woken River basin in Northeast China. River Research and Applications, 35(2), 121–132.

Haber, J. (2016). A Practical Method for Estimating the Impact of Land-Use Change on Surface Runoff, Groundwater Recharge and Wetland Hydrology. Journal of the merican Planning Association, 60(1), 95-108.

Hassan, A. Norio, T. (2009). Distributed water balance with river dynamic-diffusive flow routing model. Journal of Hydrodynamics, 21(4), 564-572.

Hoang, M. Tran, N. Wim L. and Kees, H. (2000). *Flood Vulnerability Analysis and Mapping in Vietnam*. Netherlands: Correspondence: H2iD, Geomatics Business Park Voorsterweg 28, 8316 PT Marknesse, the Netherlands.

Huggel, C. Kääb, A. Haeberli, W. and Krummenacher, B. (2003). “Regional-scale GIS models for assessment of hazards from glacier lake outbursts: evaluation and application in the Swiss Alps”. Natural Hazards and Earth System Sciences, 3(6), 647–662.

Ishaya, S. Ifatimehin, O. and Abaje, I. (2009). Mapping flood vulnerable areas in a developing urban centre of Nigeria. Journal of Sustainable Development in Africa, 11(4), 180-194.

Ismail, M. Pakhriazad, H. and Shahrin, M. (2009). Evaluating supervised and unsupervisedtechniques for land cover mapping using remote sensing data. Malaysian Journal of Society and Space, 1-10.

Jarvis, A. Reuter, H I. Nelson, A. and Guevara, E. (2008, October 1). Hole-filled Seamless SRTM Data V4. Retrieved from International Centre for Tropical Agriculture (CIAT).

Jayaseelan, A.T. (2001). Droughts and Floods Assessement and Monitoring Using Remote Sensing and GIS: Satellite Remote Sensing and GIS Applications in Agricultural Meteorology. Crop Inventory and Drought Assessment Division, 291-313.

Jeb, D. and Aggarwal, S. (2008). Flood inundation hazard modeling of the River Kaduna using remote sensing and geographic information systems. Journal of Applied Sciences Research, 4(12), 1822 – 1833.

Jemal, S. (2009). Two dimensional conservative contaminant transport modeling of the Akaki well field, “Unpublished” Thesis Submitted to Addis Abeba University, 34-45.

Jensen, J. (2004). Introductory digital image processing: a remote sensing perspective (3rd ed.). New Jersey: Prentice Hall.

Jonkman, S.N. (2005). Global perspectives on loss of human life caused by floods. Natural Hazards, 151–175.

Kebede,T. and Tadesse, H. (1990).Engineering Geological Mapping of Addis Ababa, Ethiopian Geological Survey, “Unpublished” Thesis Submitted to Addis Abeba University,45-66.

KRCS. (2013). Status of Floods in Kenya. Kenya: Environment and disaster.

Lillesand, T.m. Kiefer, R.W. & Chipman, J.W. (2008). Remote Sensing and Image Interpretation (7th ed.). New York: Wiley.

Marcus, M. and Minc, H. (1988). Introduction to Linear Algebra. New York: Dover.

Meyer, W. (1995). Past and Present Land-use and Land-cover in the U.S.A. Consequences:The Nature and Implications of Environmental Change. Nature Implications Environmental Change, 24-33.

Milly, P.C., R.T. Wetherald, K.A. Dunne and Delworth, T.L. (2002). Increasing risk of great floods in changing climate. Nature, 415, 514-517.

Mustard, J. and Fisher,T. (2004). Land Use and Hydrology,Land Change Science: Observing Monitoring nd Understanding Trajectories of Change on the Earth's Surface. Kluwer Academic Publishers, 257-276.

Nangendo, G. (2005). Changing forest-woodland-savanna mosaics in Uganda: with implications for conservation. International Institute for Geo-information Science & Earth Observation, 120-139.

Ochola, S. Eitel, B. and Olago, D. (2010). Vulnerability of schools to floods in Nyando River catchment, Kenya. Flood disasters, 34(3), 732-754.

Okoth, D. (2010). Malindi's Poor Toil to Bring Salt to the Table, Standard newspaper. Kenyatta: Maina Paul Mwangi.

Onywere, S. Getanga, Z. Mwakalila, S. Twesigye, C. and Nakuranda, J. (2011). Assessing the Challenge of Settlement in Budalangi and Yala Swamp Area in Western Kenya Using Landsat Satellite Imagery. The Open Environmental Engineering Journal, 4, 97 – 104.

Ouma, O. and Tateishi, R. (2014). Urban Flood Vulnerability and Risk Mapping Using Integrated Multi-Parametric AHP and GIS : Methodological Overview and Case Study Assessment. Water Journal, 2014(6), 1515 –1545.

Riebsame, W.E. Meyer, W.B. and Turner, B.L. (1994). Modeling Land-use and Cover as Part of Global Environmental Change. Climate Change. Climate Change, 28(1-2), 45-64.

Rosyidie, A. (2013). Flood: Facts and effects, and the effects of land use change. Journal of Urban and Regional Planning , 24(3), 241–249.

Saaty, T.L. (1977). A Scaling Method for Priorities in Hierarchical Structures. Journal of math Psychology, 234-281.

Sage, H. Xinyi, S. Efthymios, N. and Emmanouil, A. (2018). A Numerical Framework for Evaluating Flood Inundation Hazard under Different Dam Operation Scenarios—A Case Study in Naugatuck River. Water, 10, 1-21.

Sluiter, R. (2005). Mediterranean land cover change: Modeling and monitoring natural vegetation using GIS and remote sensing. Netherlands Geographical Studies, 23-31.

Soojeong, M. and Hyun, J. (2009). Developing Flood Vulnerability map for North Korea. Korea Environment Institute Seoul, 122-706.

Sunday, I. Olarewaju, O. I. and Abaje, I. B. (2009). Mapping Flood Vulnerable areas in a developing Urban Centre of Nigeria. Journal of Sustainable Development in Africa, 11(4), 180-194.

Tadesse, D. and Haile, D. (2016). Integrated Management of Vertisols for Crop Production in Ethiopia. Journal of Biology, Agriculture and Healthcare, 6(24), 2224-3208.

Tadesse, D. and Haile, D. (2016). (2016). Integrated Management of Vertisols for Crop Production in Ethiopia. Journal of Biology, Agriculture and Healthcare, 2224-3208.

Tanavud, C. Yongchalermchai, C. Bennui, A. and Densreeserekul, O. (2004). Downscaled cAssessment of flood risk in Hat Yai Municipality, Southern Thailand, using GIS. Journal of Natural Disaster Science, 26(1), 1-14.

Teller, H.L. (1967). Report Paper: Impact of Forest Land-Use on Floods. FAO Forestry Industries Division. Romania: European Forestry Commission.

Tesfa,K.(2019). Impact of LULC on surface water Quantity and Quality, Acase of Akaki Kality Catchment, “Unpublished” Thesis Submitted to Addis Abeba University, 40-60.

Turner, M. G. (1989). Landscape Ecology: the effect of pattern on process. Annual Review Ecological Systematics, 171-197.

Turner, M. G. (1989). Landscape Ecology: the effect of pattern on process. Annual Review Ecological Systematics, 171-197.

UNCHS. (2007). Global report on human settlments 2007 enhancing urban saftey and security. London : United Nation Human Settlment Program.

UNOCHA. (2006). Flood affected woredas in Ethiopia. Ethiopia: UN Office for the Coordination of Humanitarian Affaires.Https://reliefweb.int/map/ethiopia/flood-affected-woredas-ethiopia-6-sep-2006.

Wan, R. and Yang, G. (2007). Influence of land use/cover change on storm runoff a case study of Xitiaoxi River Basin in upstream of Taihu Lake watershed. Chinese Geographical Science, 17(4), 349–356.

Warburton, M.L., Schulze, R.E. and Jewitt, G.P.W. (2012). Hydrological impacts of land use change in three diverse South African catchments. Journal of Hydrology, 118–135.

Weets, G. (2011). Assessing vulnerability of urban systems. In Populations and goods in relation to natural and man-made disasters in Africa. CLimate change and Urban Vulnerability in Africa.

WHO. (2010). World Disasters Report 2010, Chapter 2 and 6: Focus on Urban Risk. France: International Federation of Red Cross. Https://www.ifrc.org/en/publications-and-reports/world-disasters-report/wdr2010/.

Woubet, G. and Dagnachew, L. (2011). Flood Hazard and Risk Assessment in Fogera Woreda using GIS and Remote Sensing. Journal of Springer Environmental Science, 179-206.

Yang, W. Long, D. Bai, P. (2019). Impacts of future land cover and climate changes on runoff in the mostly afforested river basin in North China. Journal of Hydrology, 201–219.

Yirga, K. (2016). Flood Hazard and Risk Assessment Using GIS and Remote Sensing in Lower Awash Sub-basin, Ethiopia. Journal of Environment and Earth Science, 2224-3216.

Zeleke, G. and Hurni, H. (2001). Implications of Land Use and Land Cover Dynamics for Mountain Resource Degradation in the Northwestern Ethiopian Highlands. Mountain Research and Development, 21, 184–191.

APPENDICES

Appendix i: Sets of land use land cover classes collected during field work i: Average Monthly rainfall distribution charts of 15 years both Akaki and Kality station (mm)

Appendix ii: Average Monthly Maximum and Minimum Temperature Kality station

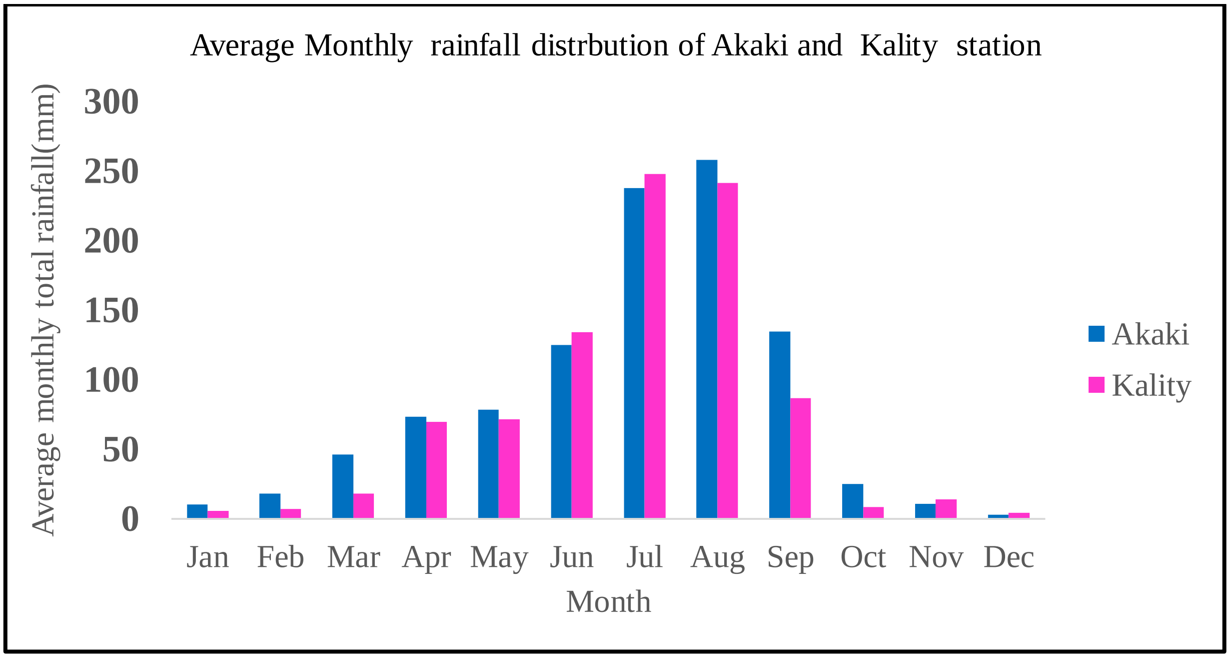
Appendix iii: Total Monthly rainfall of Akaki and Kality gauge station (mm) 2005-2019 years

Appendix iv: Distribution of reference points /GCP of land use/land cover class of flood risk

Appendix v: Sets of land use land cover classes collected during field work

Appendix vi: Drainage, Slope, Elevation, Rainfall, Soil, Land use/ Land cover and Flood risk map of Akaki Catchment

Appendix s i: Average Monthly rainfall distribution charts of 15 years both Akaki and Kality station (mm)



Average Monthly rainfall distribution charts of 15 years both Akaki and Kality station (mm)

Appendix ii: Average Monthly Maximum and Minimum Temperature Kality station

Temp MAX and MIN	Mean Monthly Temperature (℃)												Annual Mean Tem(℃)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
MAX	17	12	15.4	15.4	21.3	17.7	19.3	12.8	13.1	13.4	8.1	8.3	**14.5**
MIN	5.8	4.9	6.7	7.2	8.4	6.9	11.1	8.1	7.8	5.8	2.8	3.6	**6.6**

Appendix iii: Total Monthly rainfall of Akaki and Kality gauge station (mm) 2005-2019 years

Akaki Station

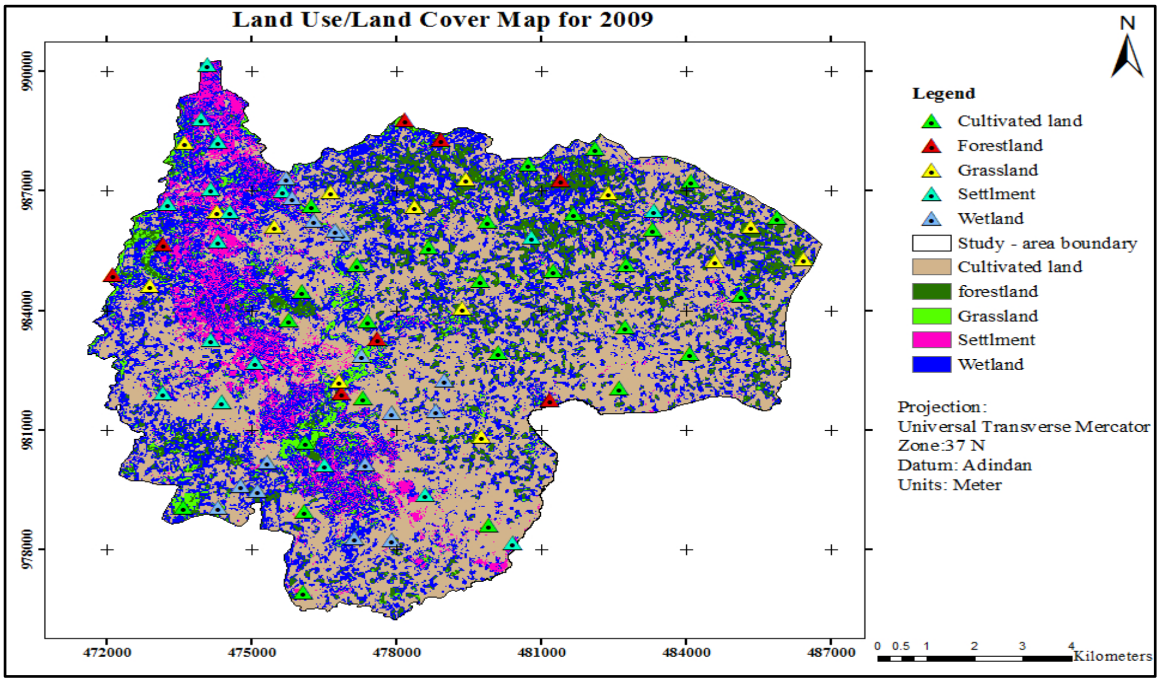
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	28.8	7.3	47.9	112.2	140.7	139.9	218.7	231.4	152.7	9.1	15.2	0
2006	2.6	44.2	56.3	79.7	22	84.3	276.4	262.6	148.1	38	0	3.2
2007	34.2	24.7	25.6	96.8	64.6	132.7	254.2	221.8	148.5	14.3	1.3	0
2008	0	0	0.6	34.2	62.4	140.2	253.5	252.3		7.2	64.8	0
2009	60.2	0	10	118.7	47.7	63.5	235.3	322.4	71.3	32.8	4	16.8
2010	0	63.8	126.2	170	95.2	164.8	334.4	169.8	154.1	5.2	14.8	7.8
2011	0	2.5	45.2	20.7	128.7	60	204.3	304	194.5	0	4.7	
2012	0	0		61	26.1	80.6	228	243.9	122.9	0	0	0
2013	0	0	77	89.1	73.4	111.5	179.6	242.4	142.5	20.6	0	0.2
2014	0	39.4	76	13.9		52.6	176.8	281.6	115.3	52.3	0	0
2015	0	0	13.7	2.3	96.5	158	187.8	247.5	70	0	14.5	
2016	0	46	39.3	184.5	134.2	105.7			119.1		9.3	
2017			46.1	22.5	70.3				177.2	0	0	0
2018						165.7	238.3	274.1	47.3	13.2		
2019	7.9	5.8	35	23.9	55.9	289.9	299.8	299.5	221.5	156.8	19.7	3.9
Av.	**10.3**	**18**	**46.1**	**73.5**	**78.3**	**125**	**237.5**	**258**	**134.6**	**25**	**10.6**	**2.9**

Kality Station

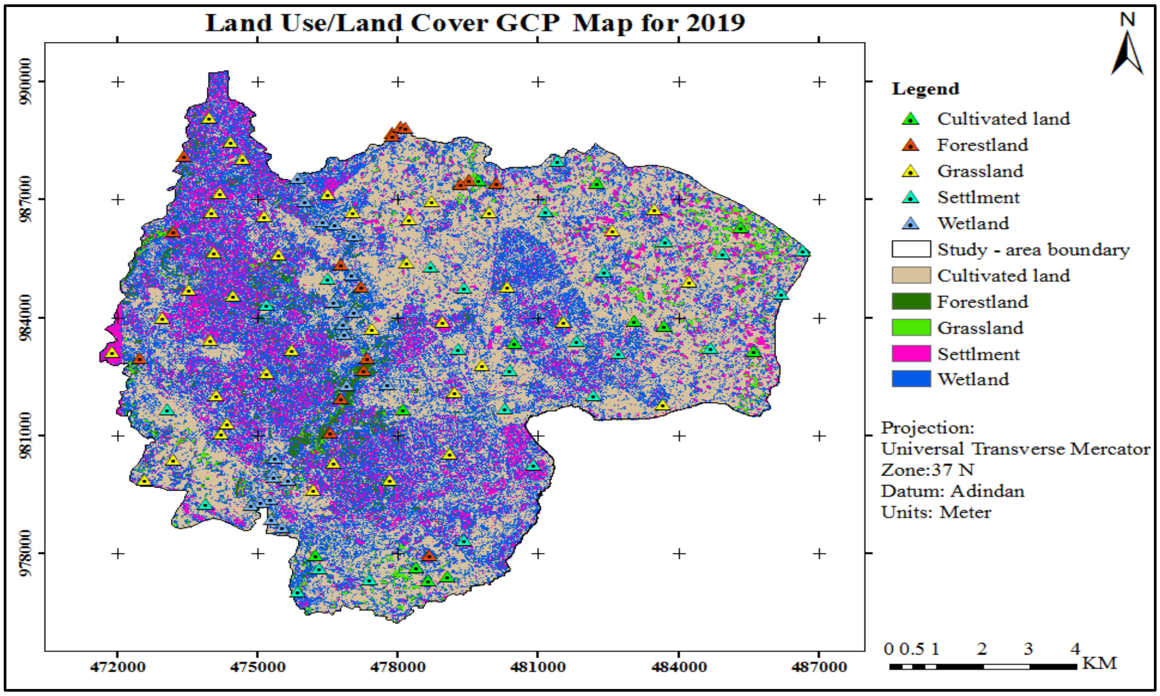
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	0		4.3		29.4	190.7	232.1	289	23		34.5	0
2006	23	0	34.8	23		178.9	245.7	245.4	56.2		45.2	34
2007						170.4			145		0	0
2008	0	2.2	0		67	101.2	255.7	258.9	184.8	30		0
2009	30	0	2			118.7	255.5	391.3	80.7	11		
2010			48	50	18		246.5					
2011	0						234.7	278.5				
2012			0		18.2	108.2	296.6	163.8	146.3	0	14.2	0
2013	0					178.7	189.5	245.6				
2014	0	37	53	29.4	79.4	52.2	184.6	247.1	88.8			
2015							248	186	109.6	0	0	0
2016		4.7	29.6	142	120.9	65	209.9	134				

2017	0	3.1		150	119.4	123.5	201.3	123	34	0	12.3	1.2
2018	1.3		3.4		23	145.8	300.4	278.4	24.7	15	0	
2019	2.5	2.2	6.2	24.7	167.8	178.5	368.9	300.4	57.8	2.3	4.3	0
Av.	**5.7**	**7.1**	**18.1**	**69.8**	**71.5**	**134.3**	**247.8**	**241.6**	**86.5**	**8.3**	**13.8**	**4.4**

Appendix iv: Distribution of reference point /GCP of land use/land cover class of flood risk



Distribution reference points /random point of land use/ land cover for 2009



Distribution Ground Control Point (GCP) of land use/ land cover for 2019

Appendix v: Sets of and use/land cover classes collected during field work

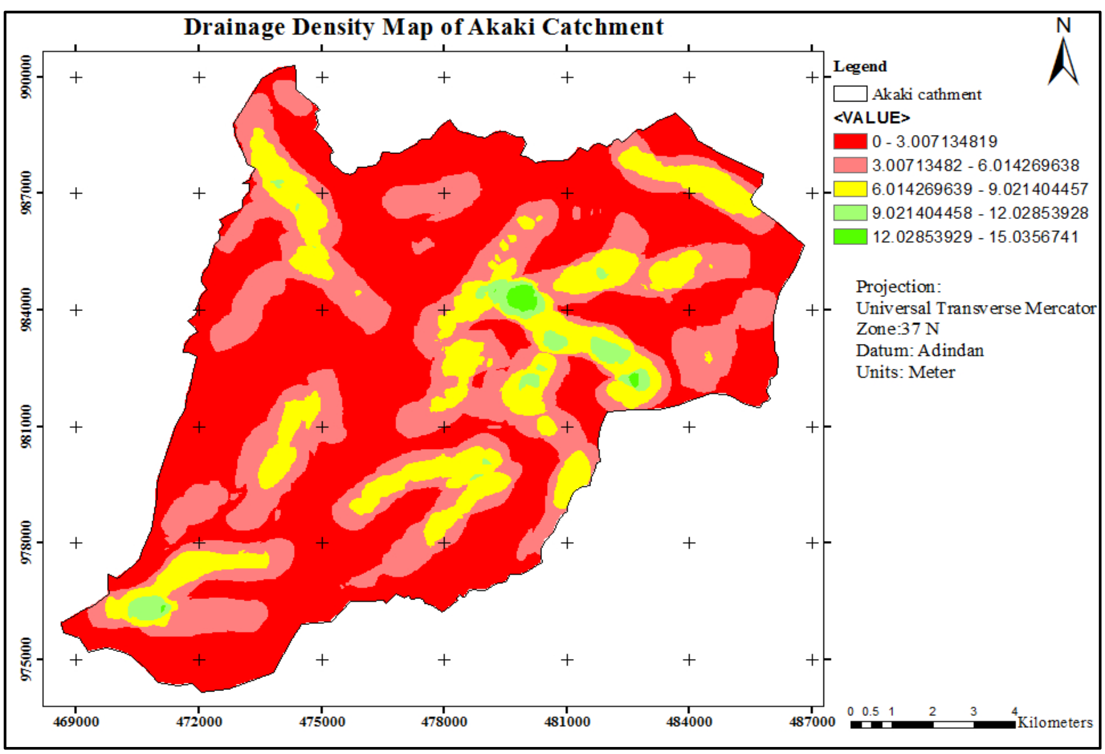
No.	X	Y	LULC type
1	479749	987486	Cultivated land
2	482274	987413	Cultivated land
3	485638	983155	Cultivated land
4	483708	983771	Cultivated land
5	485340	986301	Cultivated land
6	478404	977640	Cultivated land
7	479066	977413	Cultivated land
8	478665	977298	Cultivated land
9	476252	977953	Cultivated land
10	480508	983359	Cultivated land
11	483060	983914	Cultivated land
12	478136	981669	Forestland
13	477908	988693	Forestland
14	477886	988613	Forestland
15	478080	988859	Forestland
16	478183	988822	Forestland
17	479529	987492	Forestland

18	479361	987403	Forestland
19	477270	982662	Forestland
20	477352	982966	Forestland
21	477224	984773	Forestland
22	476788	985353	Forestland
23	472501	982954	Forestland
24	478687	977941	Forestland
25	476572	981080	Forestland
26	473436	988115	Forestland
27	473207	986201	Forestland
28	480128	987425	Forestland
29	476802	981929	Forestland
30	471911	983124	Grassland
31	474200	987160	Grassland
32	474451	988479	Grassland
33	473987	989082	Grassland
34	476520	987142	Grassland
35	475147	986574	Grassland
36	473992	983434	Grassland
37	479235	982090	Grassland
38	478979	983890	Grassland
39	475733	983159	Grassland
40	482603	986211	Grassland
41	478247	986492	Grassland
42	477844	979877	Grassland
43	480352	984770	Grassland
44	481567	983876	Grassland
45	483495	986752	Grassland
46	472986	983993	Grassland
47	474244	981048	Grassland
48	479957	986675	Grassland
49	478728	986967	Grassland
50	484244	984903	Grassland
51	472598	979859	Grassland
52	473216	980391	Grassland
53	479117	980542	Grassland
54	475210	982587	Grassland
55	478205	985393	Grassland
56	473539	984704	Grassland
57	474032	986665	Grassland

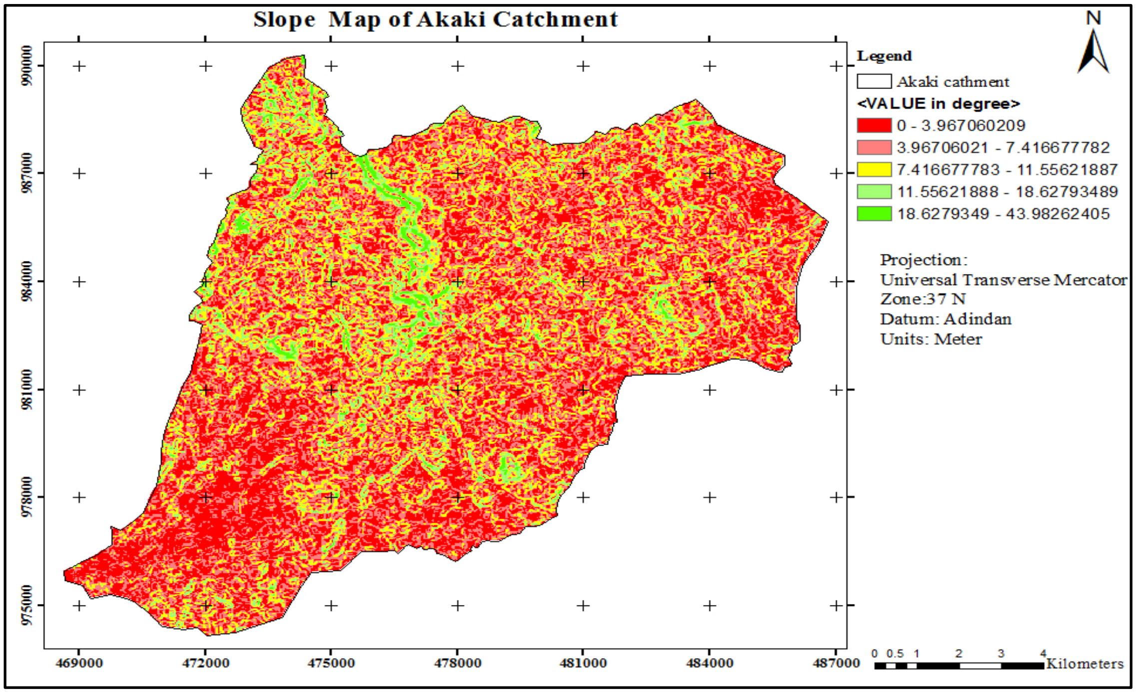
58	474695	988038	Grassland
59	474485	984544	Grassland
60	475464	985592	Grassland
61	476202	979603	Grassland
62	476631	980304	Grassland
63	474074	985652	Grassland
64	474131	982022	Grassland
65	474375	981295	Grassland
66	479827	982790	Grassland
67	477450	983695	Grassland
68	477414	977324	Settlement
69	476335	977614	Settlement
70	473896	979245	Settlement
71	480395	982657	Settlement
72	480298	981689	Settlement
73	482722	983099	Settlement
74	478726	985290	Settlement
75	486218	984603	Settlement
76	484960	985627	Settlement
77	484699	983226	Settlement
78	482435	985153	Settlement
79	483724	985945	Settlement
80	473095	981663	Settlement
81	480928	980238	Settlement
82	479441	984753	Settlement
83	476503	984976	Settlement
84	475217	984324	Settlement
85	482187	982017	Settlement
86	481844	983411	Settlement
87	486688	985703	Settlement
88	481174	986706	Settlement
89	481433	987987	Settlement
90	479291	983185	Settlement
91	475884	977019	Settlement
92	479426	978330	Settlement
93	475877	987547	Wetland
94	476016	986961	Wetland
95	476423	986434	Wetland
96	477078	984143	Wetland
97	476645	984408	Wetland

98	477804	982302	Wetland
99	475320	978880	Wetland
100	475537	978659	Wetland
101	475293	979390	Wetland
102	475070	979305	Wetland
103	474884	979239	Wetland
104	475371	980064	Wetland
105	475371	979935	Wetland
106	475674	979875	Wetland
107	475374	980437	Wetland
108	476884	983567	Wetland
109	476833	983833	Wetland
110	477019	985089	Wetland
111	477080	986077	Wetland
112	476675	986369	Wetland
113	476924	982280	Wetland
114	477060	986667	Wetland
115	483684	981775	Wetland

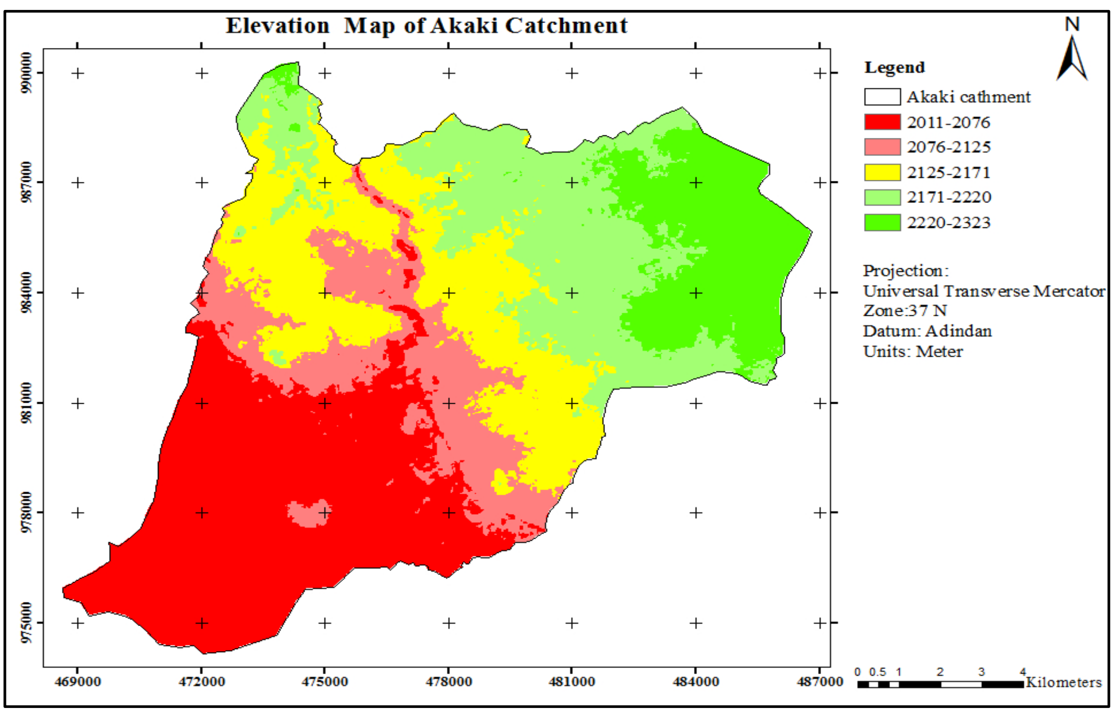
Appendix vi: Drainage, Slope, Elevation, Rainfall, Soil, Land use/ Land cover and Flood risk map of Akaki Catchment



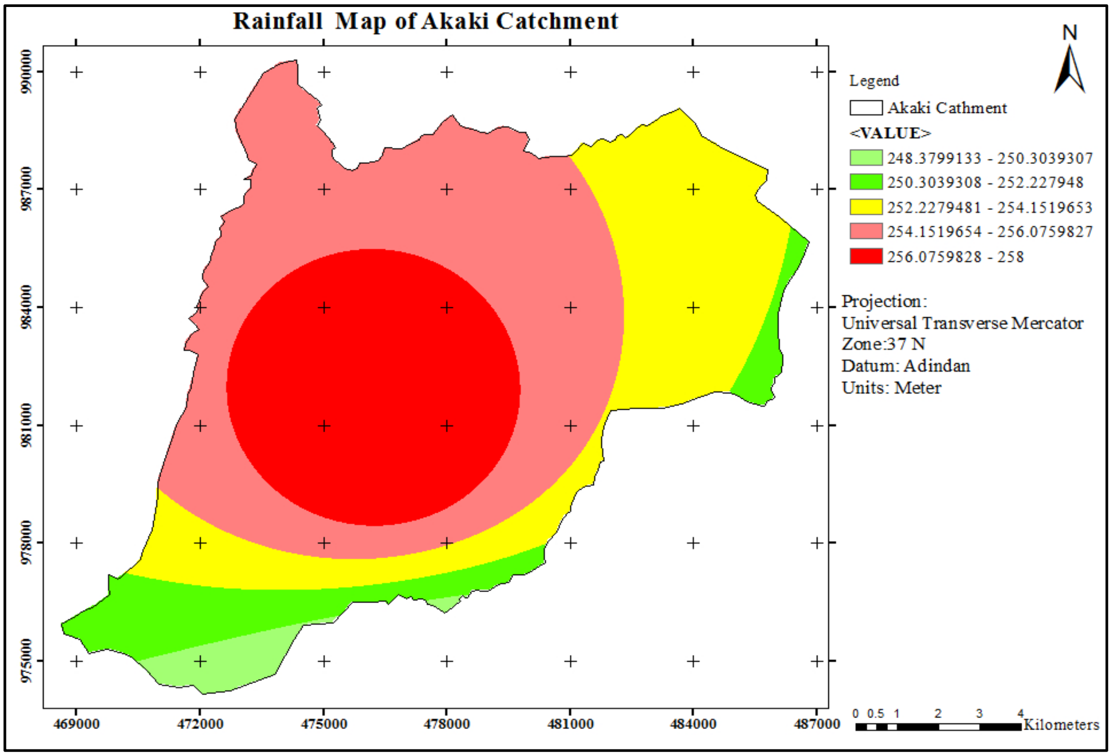
Drainage Density of Akaki Catchment



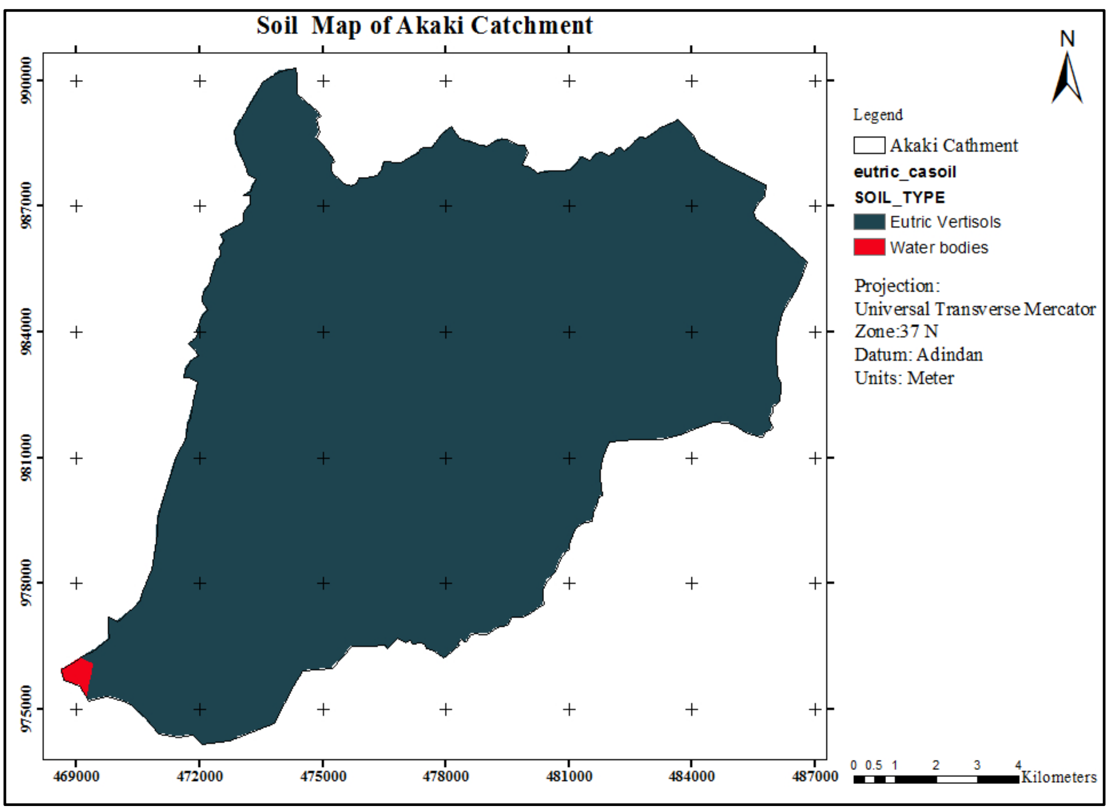
Slope of Akaki Catchment



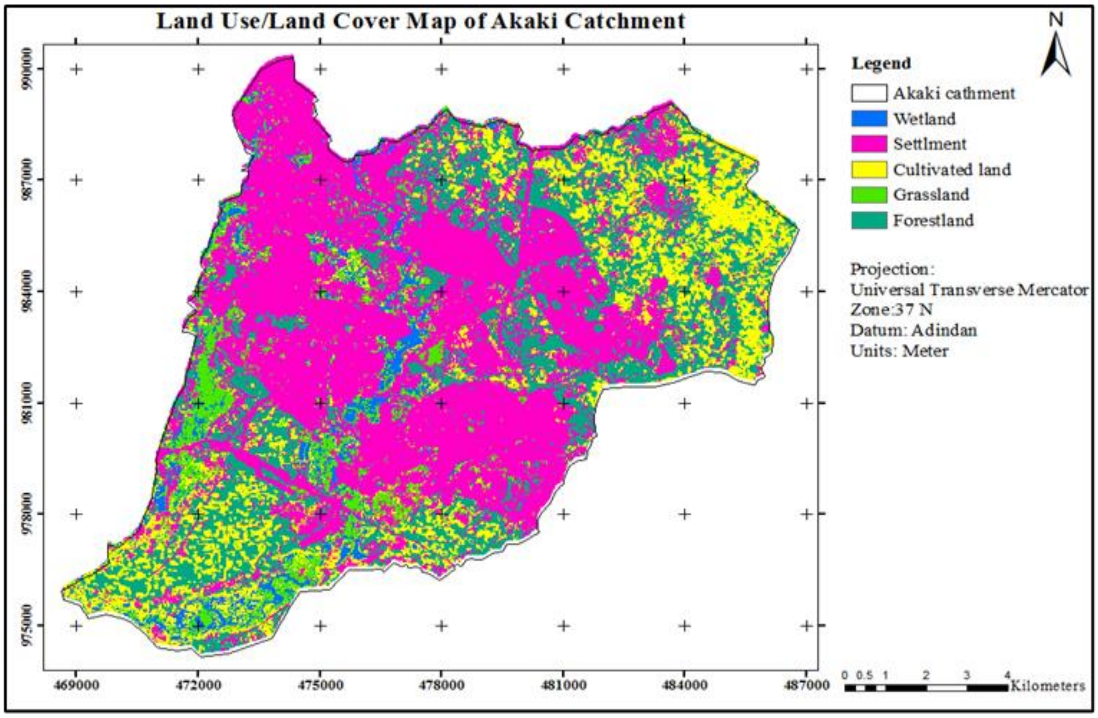
Elevation of Akaki Catchment



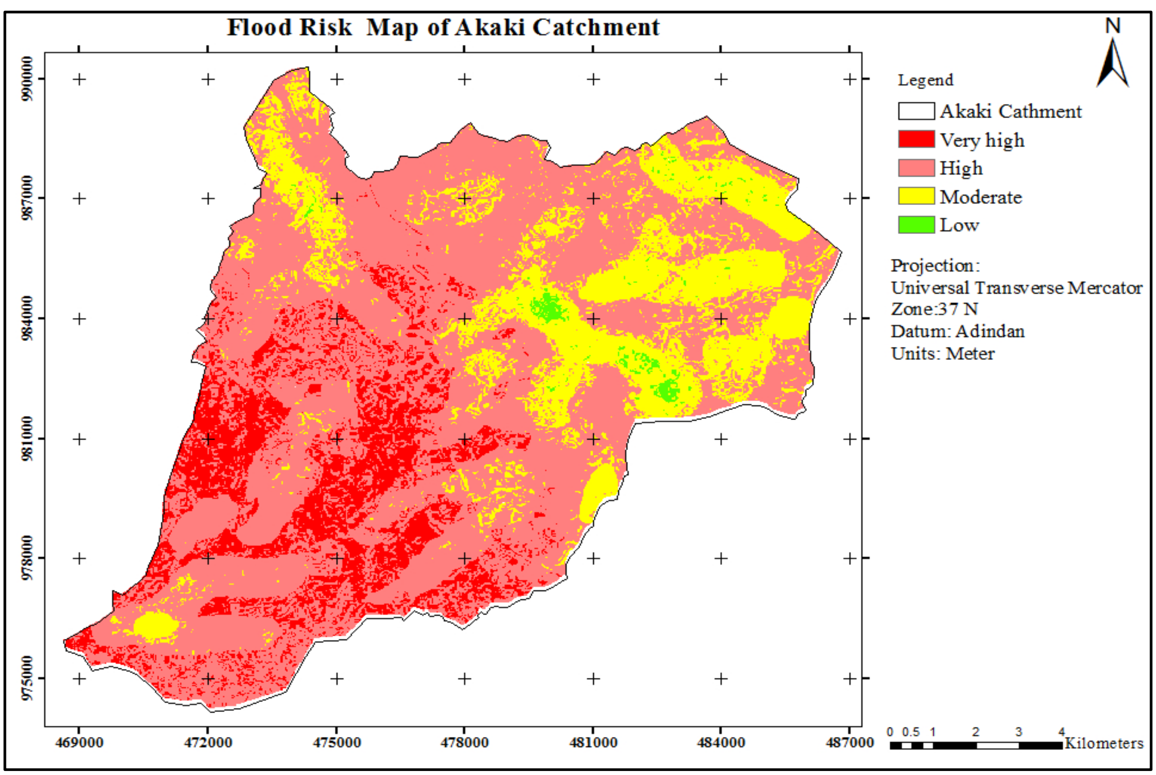
Rainfall of Akaki Catchment



Soil of Akaki Catchment



Land Use/Land cover of Akaki Catchment



Flood Risk of Akaki Catchment