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Evaluating the Spatio - Temporal Changes of Flood Risk Area in the case of Chemoga Watershed, Amhara region, Ethiopia.

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Supervisor's approval

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LIST OF ABBREVIATIONS

DEM	Digital Elevation Model
ESTC	Evaluating Spatio - temporal Change
FRM	Flood Risk Mapping
GIS	Geographic Information System`
LULC	Land use land cover
LULCC	Land use Land cover change
MCDMA	Multi Criteria Decision Making Analysis
MLCA	Maximum Likelihood Classification Algorithm
NDVI	Normalized Difference Vegetation Index
QGIS	Quantum Geographic Information System
RS	Remote Sensing
SCP	Semi - Automatic Classification Plugin
USGS	United States Geological Survey

ABSTRACT

*Flooding is one of the most common natural disasters that affect many countries or regions of the world. There is a problem of river floods occur when a river's storage capacity is exceeded, overflowing the banks and filling the nearby low-lying lands. Spatial resolution 30*30 m digital elevation model (DEM) or elevation, land use land cover, precipitation data and soil data were used. The objective of this study was evaluating the Spatio - temporal changes of flood risk area in the case of Chemoga Watershed, Amhara region, Ethiopia. Analyze the LULC change of these watershed for the year 1993, 2003, 2013 and 2023 was performed using semi-automatic plugin in quantum GIS and analyze the flood risk trend using Multi Criteria Decision Making Analysis. In the year 1993, the highest LULC classification Agricultural land 48,529.71 ha (41.56%) and Water body 35,632.35 ha (30.51%). In the year 2003, the highest LULC classification Settlement 34,482.15 ha or 29.52 % and Forest 15250.86 ha or 23.53 %. In the year 2013, the highest LULC classification Bare land 47881.26 ha or 40.99% and Agricultural land 31374.27 ha or 26.86% and also in the latest year 2023, Agricultural land 40,748.13 ha or 54.14%, Settlement 12,412.53 ha or 16.50 % and Bare land 12,351.87 ha or 16.41 %. The study had an overall accuracy of 91.4%, 92.53%, 93.34% and 93.48% in the year 1993, 2003, 2013 and 2023 respectively. The highest percentage of risk level was high flood risk 3388.52 ha, (66.56%), 85220.19 ha, (77.29 %), 85003.65 ha (77.09%) and 87516.72 ha (79.37 %) and also the lowest percentage was low flood risk (2018.61 ha (1.83 %), 496.35 ha (0.45 %), 600.12 ha (0.54 %) and 418.77 ha (0.38 %)% in the year 1993, 2003, 2013 and 2023 respectively and, so requires further action to reduce these risk.*

Key Words: Chemoga Watershed, Flood risk area and Land use land cover change

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

One of the natural disasters impacting many nations or areas of the world are flooding *(Teh and Khan 2021).* Floods that occur in Ethiopia during the rainy season have had an impact on resources and people over time *(Beshir and Song 2021).* Water floods outside of the bodies of water as a result of it. Extreme weather carried on by snowmelt, dam failure, unexpected flow of water, or the inability of the land to quickly absorb surface water from the ground and release it when it rains *(Akhtar, Syakir Ishak et al. 2021).*

Many things can lead to flooding, including heavy downpours at river mouths, ice jams, melting snowpack, and modifications to land use (such as urbanization and deforestation) *(Angelakis, Capodaglio et al. 2023*). The primary source of river floods are runoff from periods of penetrating precipitation; moreover, as urbanization increases, increasing runoff rates *(Rincón et al., 2018).* By combining assessments of Spatio - temporal changes of flood risk areas, decision makers can gain insights into how these areas are evolving and where to focus resources and efforts to successfully manage it. This information can help prioritize spending on early warning systems, infrastructure, land use planning, and community resilience-building initiatives in areas most vulnerable to floods *(Munawar, Khan et al. 2021).*

To identify regions at high risk of flooding, a variety of criteria including spatial resolution 30*30 m digital elevation model (DEM) or elevation, land use land cover (LULC), climate patterns, hydrological data and also infrastructure were analyzed *(Zzaman, Nowreen et al. 2021)*. Decision-makers can reduce vulnerability to flooding events by prioritizing locations for mitigation measures, emergency response planning, and land use management by mapping flood risk geographically *(Büchele et al., 2006).* Geographic information system (GIS) and Remote sensing methods are useful tools for a variety of applications in flood risk management, including mapping, modeling, and analysis *(Wang and Xie 2018).*

The Chemoga watershed is the Upper Blue Nile basin, located south of Lake Tana and the river flow starts from the Choke Mountain at an elevation of 4000 m above mean sea level. Using

remote sensing data, satellite images to analyze the land use land cover (LULC) changes of the year 1993 up to 2023 for 30 years. So identifying the environment and conditions in which flooding can occur, as well as recognizing the relevant authorities it's ready to give *(Burningham, Fielding et al. 2008).*

1.2. Statement of the problem

There is a problem of river floods occur when a river's storage capacity is exceeded, overflowing the banks and filling the nearby low-lying lands *(Nakajima and Umeyama 2015)*. This causes significant social, economic, and environmental effects, such as the loss of life (*Ward et al., 2018*) and negative effects on the population, damage to infrastructure and essential services, damage to crops and animals, spread of diseases, and contamination of the water supply. Since floods are caused by the growing population and the accompanying expansion of oil wood, coal production, as well as farms and villages, it is important to identify the areas that are at risk and develop a map to mitigate their impact on the economy, communities and humanity *(Rincón et al., 2018).*

Flooding poses significant risks to communities, infrastructure, and the environment in the Case of Chemoga River, Amhara Region, Ethiopia, particularly during the heavy rainy season from June to September. Factors such as rapid urbanization and land use changes further complicate flood risk management *(Salman and Li 2018).* The flooding leads to soil erosion and loss of agricultural land, highlighting the urgent need for flood risk area and mitigation strategies *(Salman and Li 2018).* Relating sustainable flood mitigation methods is crucial for managing the problem effectively and reducing the damage caused by flooding in the region *(Dixit 2003).*

The KINEROS model application gives satisfactory results in peak flow simulations of the Rayna River for particular flood events. It gives opportunity to assess the influence of the LULC changes based on different scenarios on the peak flow and further more to assess the flood risk. Its implementation on other territories with similar landscape structure would give opportunity to receive more general and practical results.

1.3. Objectives

1.3.1. General Objective

The general objective of this study is evaluating the Spatio -Temporal Changes of Flood Risk Area in the case of Chemoga Watershed, Amhara region, Ethiopia.

1.3.2. Specific Objectives

1. To analyze the Land use land cover changes of Chemoga Watershed in the year 1993, 2003, 2013 and 2023.
2. To analyze flood risk trend using Multi - Criteria Decision Making Analysis**.**

1.4. Research Questions

To address the above objectives, the following research questions are raised:

- ✓ What are the main changes to analyze the Land use land cover changes in the area of Chemoga watershed?
- ✓ How to analyze flood risk trend using Multi - Criteria Decision Making Analysis?

1.5. Significance of the study

The following crucial elements highlight the need to carry out this study: During extreme weather events, the study can help minimize damages, save lives, and determine the potential impact of floods by focusing on high-risk locations and putting necessary precautions in place. Resource Optimization: Decision-makers can improve resource use and maximize the efficiency of flood management activities by assigning limited resources to regions with the highest flood risk and potential damage.

This guarantees the best use of the available resources, leading to an economical strategy for reducing the risk of flooding and building community resilience. The ability to understand the flood risk dynamics, support targeted management strategies, enhance resilience, and optimize resource allocation for efficient flood risk reduction and management strategies, all things considered, the significance of conducting this study based on mapping and evaluating spatial-temporal changes of flood risk area in terms of space and time. The result of these analysis used to prioritizing flood control management strategies.

1.6. Scope of the study

The scope of this study were focuses on identify the risk area of Chemoga Watershed within the Amhara Region of Ethiopia. It involves creating flood risk maps, analyze the Land use land cover classification, Land use land cover (LULC) changes over time. This considers different factors such as land use, elevation, rainfall patterns, slope and soil to recommend effective measures to mitigate river flood risk and minimize its impact on the area.

1.7. Thesis Organization

The paper is organized in to five chapters: chapter one is an introduction part including the background of the study, statement of the problem, objectives (general and specific), research questions, significance and scope of the study were discussed. In chapter two, review of related literatures where the general concepts of GIS, RS, LULC and its change, flood concept include flood characteristics, impact of flood, flood hazard and flood risk area and its map. Chapter three describes data and its sources, software's, description of the study area and methodology. Chapter Four describes result and discussion and also Finally, Chapter Five describes conclusion and recommendations of the study were provided.

CHAPTER TWO

2. LITERATURE REVIEWS

2.1. General Concepts

2.1.1. GIS

GIS is an effective tool for managing natural hazards and assessing risk. Areas that are vulnerable to flooding might already be marked on a map. It offers a wide range of tools for identifying flood prone locations or predicting areas that are likely to flood as a result of a high river discharge. When spatial data are integrated into a geographically and physically-based information system. A lot of data is assembled from various sources aerial photos, satellite images and digital elevation models (DEM) using geographic information systems. Current risk maps can be one of the most useful resources for preventing significant social and financial losses caused by flooding, as well as enhancing public safety *(Odeyemi & Peter, 2017).*

For many flood risk management tasks, including base mapping, topographic mapping, and post disaster verification of mapped floodplain extents and depths, GIS is therefore ideally suited. Following their entry into a different database, attribute values were connected to the relevant map location *(Odeyemi & Peter, 2017).* GIS is helpful in gathering and disseminating a lot of data about the river and the study area. Flood danger was determined to outweigh the difficulties associated with using GIS and the procedure for collecting and recording data, despite certain drawbacks *(Rincon, Khan, & Armenakis, 2018).*

2.1.2. Remote Sensing

One useful technique for evaluating the danger and hazard caused by water is remote sensing (RS). It is used to extract information from data collected by sensors on distant platforms, most often airplanes and satellites. The use of satellite imagery has grown in significance for risk and hazard assessment due to advancements in picture quality, stereo capabilities, and digital image processing techniques. Planning flood control and related operations need accurate and timely information about flooded areas, river behavior and layout before, during, and after floods. Conventional ground surveys make it exceedingly difficult to obtain this kind of information and it quickly monitoring areas that have flooded is remote sensing.

Information is being recorded by a broad variety of satellites at different temporal, spectral, geographical, and radiometric resolutions. Almost real-time satellite photography facilitates timely decision-making by detecting floods. Numerous studies have effectively employed spectral analysis and temporal satellite imagery to monitor flooded areas and croplands *(Gumma et al., 2022).*

2.1.3. Land use land cover changes

Several methods are available for image classification from satellite remotely sensed data. They all fall under two main categories in common: unsupervised and supervised classification. In unsupervised classification, the nature of land cover features can be broken down into land classes by their spectral similarity inherent in the images. This method does not require the prior knowledge of ground cover before classification. On the contrary, supervised classification uses the predefined spectral signatures of land surface in order to train a classification algorithm and subsequently classify an entire image. Thus, the availability and quality of training data highly influences the classification accuracy *(Damtea, Kim et al. 2020).*

The training data contains the 'correct' label for each land cover type, and is used to establish the respective spectral signature of each land class. This dataset can be obtained in a variety of ways. Ground-based field survey is preferable to remote sensing and image interpretation, yet often impractical or too expensive for large regions, especially in Ethiopia. To overcome this obstacle, an image sampling method was used in recent research to synthesize pseudo training dataset by using Google Earth Pro at training locations. Google Earth Pro is available free of charge and offers high spatial resolution images, allowing multi temporal analysis of landscape changes over time *(Damtea, Kim et al. 2020).*

2.2. Flood concept

2.2.1. Flood

Scholars hold varying opinions regarding how flooding should be conceptualized, depending on its causes, effects, scope, or a mix of these elements. Flooding is defined as a region that is unexpectedly flooded due to a dam failing or an extended period of intense rainfall, posing a risk to the lives and property of those living there. When a community's ability to function is seriously disrupted and there are significant losses and impacts whether human, material, economic, or

environmental that beyond the community's capacity to recover on its own, the occurrence is classified as a disaster *(Ntajal, Lamptey et al. 2017).*

2.2.2. Flood characteristics

The characteristics or criteria used to assess the potential impact of floods are what make them dangerous. According to Doswell III (2003), the greater the energy of water movement during floods, the faster the water flows and, consequently, the greater the possibility that the floodwater would inflict damage. The length, frequency, size, and intensity of floods all influence the degree of impact (Llantwit School, 2010). Four characteristics of floods were defined by the University of Wisconsin *(Disaster Management, 2015):* Water has a greater eroding power at high flow velocities, which can ruin land or structures or carry away plants. Deep water submerges land, which may have an impact on the survival of vegetation and pose a risk to property.

2.2.3. Impacts of flooding

Floods can have both beneficial and detrimental effects. Fertile soil on riverbank flood plains, household water use, flat, livable plains, and water transportation are a few examples of the benefits that keep people from moving to safer areas. The harm that floods do to people and the environment as a result of water moving in an unpredictable manner and submerging or washing away trees and agricultural land are among the negative effects of floods.

2.2.4. Flood hazard and its map

According to Odeyemi and Peter (2017), a hazard is defined as "a dangerous phenomenon, substance, human activity, or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage." and also flood hazard is a result of the watershed's causing elements, which include slope, elevation, soil type, distance to rivers, drainage density, and rainfall distribution. The approach described here for incorporating hazard and vulnerability data into a risk analysis makes it possible to identify and classify flood risk at a reasonable cost. The process of identifying regions with a specific return period flooding probability is known as flood hazard mapping *(Semaw et al., 2022).*

Numerous hydrological parameters, including flood velocity and inundated depths, influence the degree of flood hazard *(Ukumo et al., 2023).* The relevant local authorities can greatly value the information, and the maps in particular, and use them in their risk reduction strategies. This

approach can be used in other places where flooding disasters are a concern. It is especially helpful in places where there is absolutely no risk information. A reasonable framework for evaluating flood threats is represented by the hazard map. The study area's risk analysis makes it possible to identify locations with varying levels of crisis, which is a crucial first step in developing additional risk-reduction strategies *(Odeyemi & Peter, 2017).*

2.2.5. Flood risk and flood risk map

In order to help officials with planning and mitigation activities, flood risk mapping has grown in importance as a tool for evaluating flood risks in study regions. This technology hasn't been used to assist with flood risk analysis, though. Precipitation, height, slope, soil texture, LULC, and flow accumulation are some of the environmental elements that determine flood risk zones *(Enomah, Downs et al. 2023).* Assessing flood risk entails determining the following: a) the origins of the hazard; b) the frequency of flood events; c) the location and identification of areas susceptible to flooding; d) the depth of floods; e) the duration of the flood; and f) the elements at risk (valuable materials and people).

An increasing degree of exposure to the elements that are under threat is the primary driver of an increase in flood risk. Flood risk maps represent a spatial integration of the hazard, exposure and the level of vulnerability *(Odeyemi and Peter 2017).* They successfully merge flood hazard and vulnerability maps to provide a comprehensive picture of risk. For effective flood risk management, risk maps must therefore be continuously updated and monitored. Therefore, it is important to examine the flood process in flood risk assessment. This can be achieved by examining the physical, health, and social vulnerabilities to flooding in the Hazard and Vulnerability analyses *(Odeyemi & Peter, 2017).*

Flood risk map derived from food hazard level and elements at risk (weight, %) is called a food risk map by using the general risk equation shown below *(Shook, 1997).*

$$\text{Flood Risk} = (\text{Elements at risk } (\%)) * (\text{Hazard value}) \qquad \text{Equation (1)}$$

Finally, flood risk map classified into very high, high, moderate, low and very low risk zones *(Semaw et al., 2022).*

CHAPTER THREE

3. METHODOLOGY

3.1. Description of Study Area

The study is located Chemoga watershed East Gojjam Zone of the Amhara region, which is roughly 340 km to the north-west of Addis Ababa and latitude of 10°0′0″ to 10° 35′ 0″ North and longitude of 35°25′0″ to 37°55′0″ East. Chemoga Watershed (area 116929.92 hectare) is the upper Blue Nile basin which is the elevation of 1200 up to 4000 meters above mean sea level.

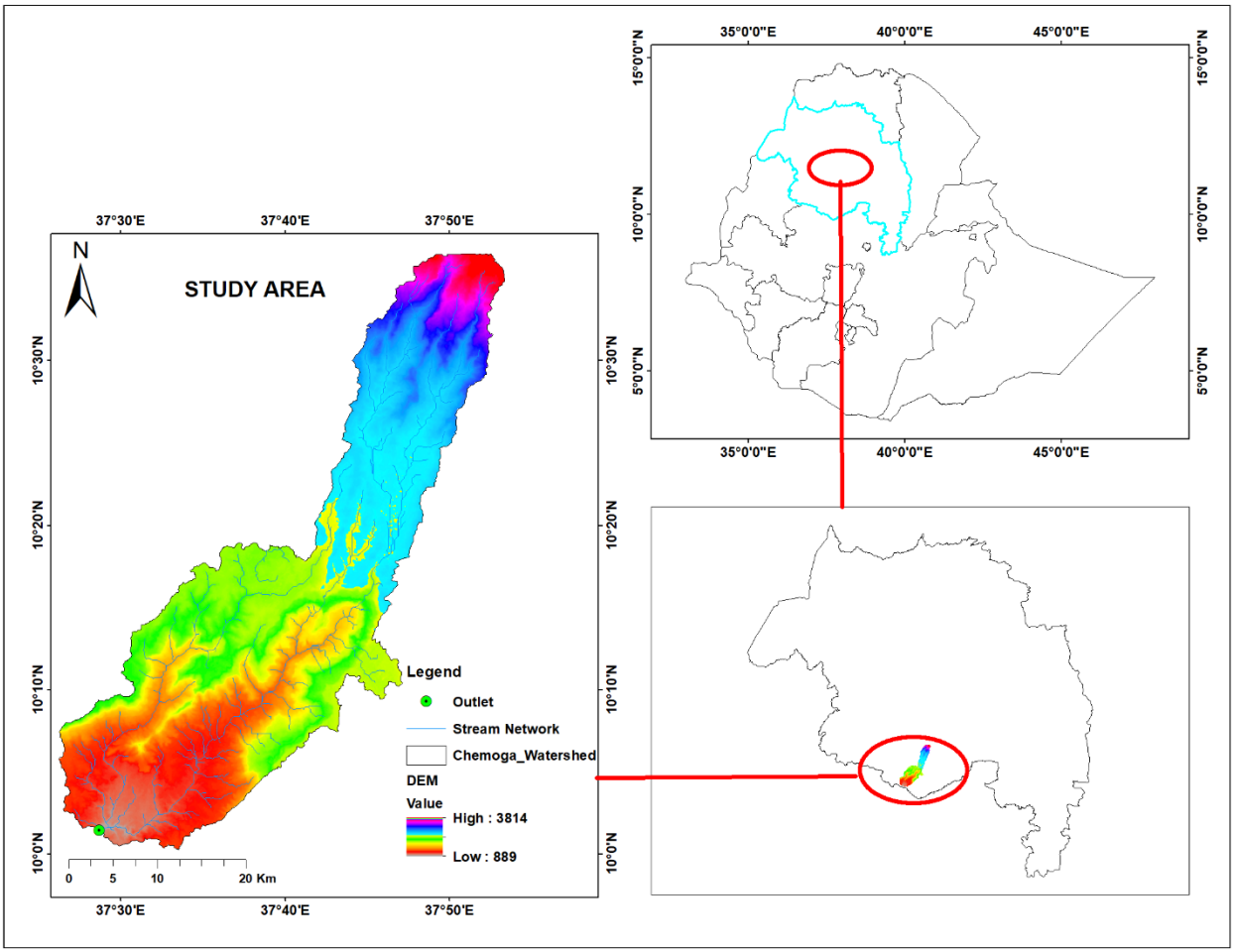


Figure 1. Study Area

3.2. Data and Software's

Table 1. Types of data and its Sources

Data	Purpose	Source
Satellite images 1993,2003, 2013 and 2023	Classification, Accuracy assessment and Land use land cover changes	USGS (Website)
DEM	To generate Elevation, Slope and Drainage density.	USGS (Website)
Road Shape file	To determine the distance to road	OpenStreetMap
Boundary of study area	Region, Zone, Woreda and Kebele.	www.gadm.org website
Soil data	To reclassify soil types based on flood risk	FOA
Precipitation data	To reclassify flood risk level.	Chirps dataset

3.2.1. Satellite Imagery

Different data sources were used to collect and analyze both primary and secondary data. This study uses remote sensing and a geographic information system to gather data on how much change area, there has been during the last 30 years of the study period. The United States Geological Survey (USGS) website (http://www.earthexplorer.usgs.gov) provided the temporal satellite pictures of the years 1993 (Landsat 4-5 TM), 2003 (Landsat 7), 2013 (Landsat 8-9 OLI) and 2023 (Landsat 8-9 OLI or Operational Land Imager), which were used to the necessary data *(Bekelea, Yina et al.).* Landsat 4-5 TM (Thematic Mapper) provided to users as Level 1 terrain corrected (L1T) data and distributed under the GEOTIFF format with the Universal Transverse Mercator (UTM) projection and the World Geodetic System 84 (WGS84) datum.

Landsat 7 Enhanced Thematic Mapper (ETM+) images consist of eight spectral bands with a spatial resolution of 30 meters for bands 1 to 7. The Land sat 8 satellite with OLI sensor consists of nine spectral bands in the panchromatic, visible and near-infrared bands with a spatial resolution

of 15 to 30 m and two thermal bands with a spatial resolution of 100 m and a temporal resolution of 16 days. In the present study, bands with a spatial resolution of 30 m have been used. Landsat 8 images have different spectral bands to monitor flood and its risk levels, making it possible to produce spectral indices *(Farhadi and Najafzadeh 2021)*.

Table 2. Landsat imagery used for this study (source: USGS platform)

No	Satellite Sensor	Resolution (M)	Platform	Path	Row	Date	Band numbers
1	TM	30	Landsat 4-5	169	053	February 16, 1993	7
2	ETM+	30	Landsat 7	169	053	February 04 ,2003	9
3	OLI	30	Landsat 8-9	169	053	March 28, 2013	8
4	OLI	30	Landsat 8-9	169	053	February 19, 2023	8

3.2.2. LULC Classification

The process of analyzing Land Use and Land Cover changes using quantum geographic information system (QGIS) and the semi – classification plugin (SCP) plugin involves a combination of preprocessing (layer stack), band processing (clustering and classification) and post-processing (accuracy assessment and change detection). Five different types of Land Use and Land Cover classification has been identified for Chemoga watershed. These are agricultural (cultivated land), forest land, settlement (urban), water body and bare land include like Grass land, Shrubs and bush land.

Table 3. Description of LULC types considered in image classification

LULC Type	Description
Settlement (urban)	Area where dominantly covered by dense houses, permanent concentration of building and other manmade structures.
Agricultural land	Areas used for rain fed crop production and scattered rural settlements usually associated with cultivated lands and also included temporary vegetation followed by using harvest length and pastures.
Barren land	Land covered by bare land with a little mix of grasses.

Forest	Areas covered with dense trees, which include afro - alpine, eucalyptus and coniferous trees, and river trees.
Water body	The land area covered by water resources and water logged and swampy like ponds, Lakes, reservoirs, streams and rivers.

The LULC of the Chemoga Watershed was prepared by classifying in Table 2, above listed. A supervised classification method was adopted using Q GIS software and later analyzed using ArcGIS spatial analyst tools as shown in Figure 7. The LULC pattern of the Chemoga catchment has been classified into 5 categories, namely Settlement (urban), Agricultural land, bare land, Forest and Water body. LULC types were ranked into different categories based on sensitivity to flooding.

Maximum Likelihood Classification Algorithm (ML) has been an appropriate choice, because it is an extremely simple and easily implemented algorithm, but at the same time, is very well known and has successfully applied to a broad range of remote sensing problems. Therefore in this study, supervised classification (ML) has been done on the image processing software (Q GIS) by Semi classification plugin for the land use land cover classification *(Twisa & Buchroithner, 2019).*

3.2.3. Accuracy Assessment

Classification accuracy was assessed by comparing land classes in the classified images with ground truth data *(Damtea, Kim et al. 2020).* An assessment of the LULC map accuracy was made to evaluate the reliability of the classified images. The accuracy is comparing data collected in the field or data from higher spatial resolution imagery to a classified map. Assessment of classification accuracy 1993 and 2023 images have been carried out to determine the quality of information derived from the data. After classification has completed, reviewing the classification result has been done the next step in determining whether the classification is accurate since it shows how the findings correspond to the reality on the ground.

The number of pixels per class for the reference data is shown in the columns of the matrix, while the number of pixels per class for the classified image is shown in the rows. Overall, user's and producer's accuracy has been determined to evaluate the classification accuracy. The overall accuracy is used to indicate the exactness of the whole classification and the other two measures indicate the accuracy of individual classes. User's accuracy: - the number of correctly classified

pixels in each class is divided by the total number of pixels classified in that category expresses the user's accuracy. It calculates the chance that a pixel on the ground categorized into a specific category really indicates that category *(Tadesse, 2019).* It is calculated by using the formula given by Equation (2) as below.

$$\text{Users Accuracy} = \frac{\text{number of correctly classified pixels in each category} * 100}{\text{Total number of classified pixels in that category (the row total)}} \quad \text{Equation (2)}$$

Producer's accuracy: - the producer accuracy indicates how effectively a reference pixels of the ground cover type are classified. According to *Tadesse (2019*) on the study it is computed by dividing the number of correctly classified pixels of certain land-use and land-cover type by the total number of pixels of the same land-use and land-cover type in the reference data as shown by Equation (3) below.

$$\text{Producer Accuracy} = \frac{\text{number of correctly classified pixels in each category} * 100}{\text{Total number of classified pixels in that category (the column total)}} \quad \text{Equation (3)}$$

The overall accuracy which is used to show the accuracy of the whole classification is computed by dividing the total correctly classified pixels by the total number of pixels multiplied by a hundred. Mathematically, it is computed by the formula given below by Equation (4);

$$\text{Overall Accuracy} = \frac{\text{Total number of correctly classified pixels (diagonal)} * 100}{\text{Total number of reference pixels}} \quad \text{Equation (4)}$$

The kappa coefficient, which is a measure of agreement, can also be used to evaluate classification accuracy. It expresses the ratio in error caused by a classification process versus the error generated by a purely random classification. It includes the element along the off diagonal of error matrices (i.e., classification errors) and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance *(Tadesse, 2019*).

3.2.4. Land Use Land Cover Changes

LULC change has been carried out using satellite imagery from year 1993 up to 2023 by 10 years interval for 30 year 1993 - 2003, 2003 - 2013 and 2013 - 2023. In this study, post classification comparison (map-to-map comparison) methods has been favors for a variety of reasons that occur in the Watershed over the study period. This approach, minimizes the problems of multi-temporal

images acquired by many sensors under a variety of climatic and environmental conditions and also provides a useful information on the amount and type of change (i.e., 'from-to').

According to Gashaw et al. (2018), the percent and rate of change of each LULC has been calculated by using Equation (5) and Equation (6) respectively as shown below.

$$\text{Percent Change} = \frac{Ay-Ax}{A} * 100 \qquad \text{Equation (5)}$$

Where; Ax = Initial area of land use land cover, Ay = Final area of land use land cover and

A = Total area

$$\text{Rate of change of } \left(\frac{\text{ha}}{\text{year}}\right) = \frac{Ay-Ax}{T} \qquad \text{Equation (6)}$$

T: is the time interval between Ax and Ay in years.

3.3. GIS-Based Multi-Criteria Approach

The weighted overlay analysis is one of the approaches applied to multi-criteria problems. Flood hazard mapping requires the determination of contributing factors to flooding in an area. The amount, degree or percentage of factors for flooding in a certain area can decide the flood hazard in that area. This flood hazard controling factors have no similar effect in flooding. They are assigned different weights for the hazard they contribute. So, GIS integrated with Multi-criteria Decision Making Analysis (MCDMA) provide more flexible and more accurate decisions to the decision makers in order to evaluate the effective factors causing flooding *(Yahaya, 2008).*

In addition, all of the maps were reclassified in a scale from 1 to 5, using the Reclassify Tool in Arc Map, where 1 refers to very low (e.g., low flood risk), and 5 is a very high level of flood risk. After reclassifying the maps, the Weighted Overlay Tool of Arc Map was used to carry out the spatial overlay of the maps. So, finally flood risk map was produced as one factor input for modeling flood risk as stated in the above equation (1). Arc GIS develop a system to do the overlay analysis of all factors in its spatial analysis tool. Here eight controling factors are taken as the main concerning conditions according to the Chemoga watershed elevation, slope, precipitation, distance to river, drainage density, Land use land cover (LULC), soil and distance to road are the factors of overlay analysis was done for flood hazard. All those flood causative factors particularly are classified in to specific classes and overlay using their weight value given.

3.3.1. Elevation

Elevation plays an important role in flood severity and for the determination of a flood risk area. it has a direct effect on flow size and runoff velocity and flood-prone areas mostly have low elevation *(Krumbien, 2002).* Elevation raster layer was derived from the Digital elevation model (DEM). The elevation raster layer was further reclassified in five sub groups using standard classification schemes in Table 8. 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 as shown (Figure 2).

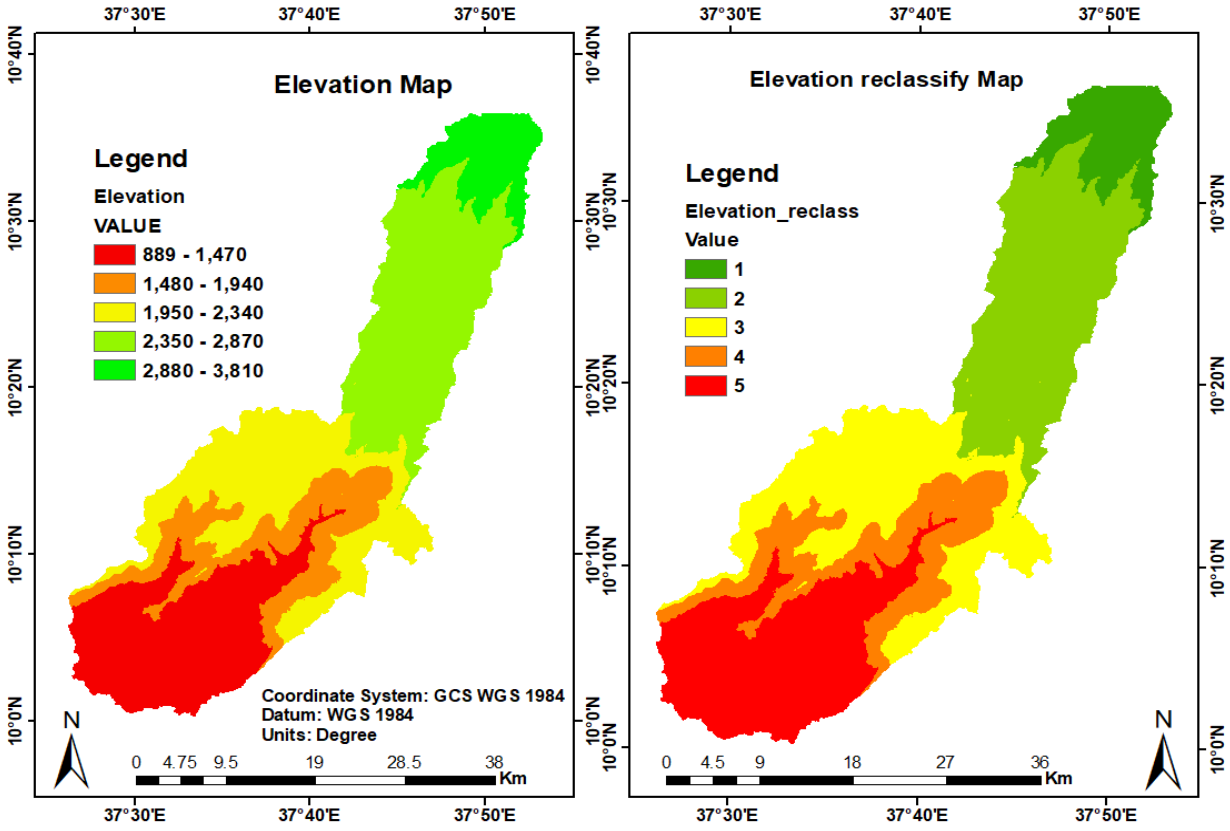


Figure 2. Elevation and elevation reclassify map.

3.3.2. Slope

The slope of Chemoga watershed was done from the elevation (DEM) using the spatial analysis surface tool and clips it to fit exactly to the study area. Slope shows how much the area is steeper or gentle. We can get slope either in degree from 0 to 90 or in percentage. Slope has effect on flooding the movement of flood and the speed depends on slope of the surface area the higher the

slope the higher probability of flooding because there is movement of water from higher slope area to lower slope area. After slope generate, classification was done in five classes using equal interval which gives new value for each class. Steeper slopes are more susceptible to surface runoff, while flat terrains are susceptible to water logging (*Krumbien, 2002*).

The slope affects the velocity in which the water is conveyed through the drainage channel and the watershed. The slope raster layer was further reclassified in five sub group using standard classification schemes. The reclassified slope is given a value 1 to 5 with the higher value,5 showing high influence in resulting very high flood rate, while the lower value,1 showing very low influence in resulting very low flood rate. Therefore, the slope classes having less values was assigned higher rank due to almost flat terrain while the class having maximum value was categorized as lower rank due to relatively high run-off. For the case study, the results of reclassified slope layers are presented (Figure 3).

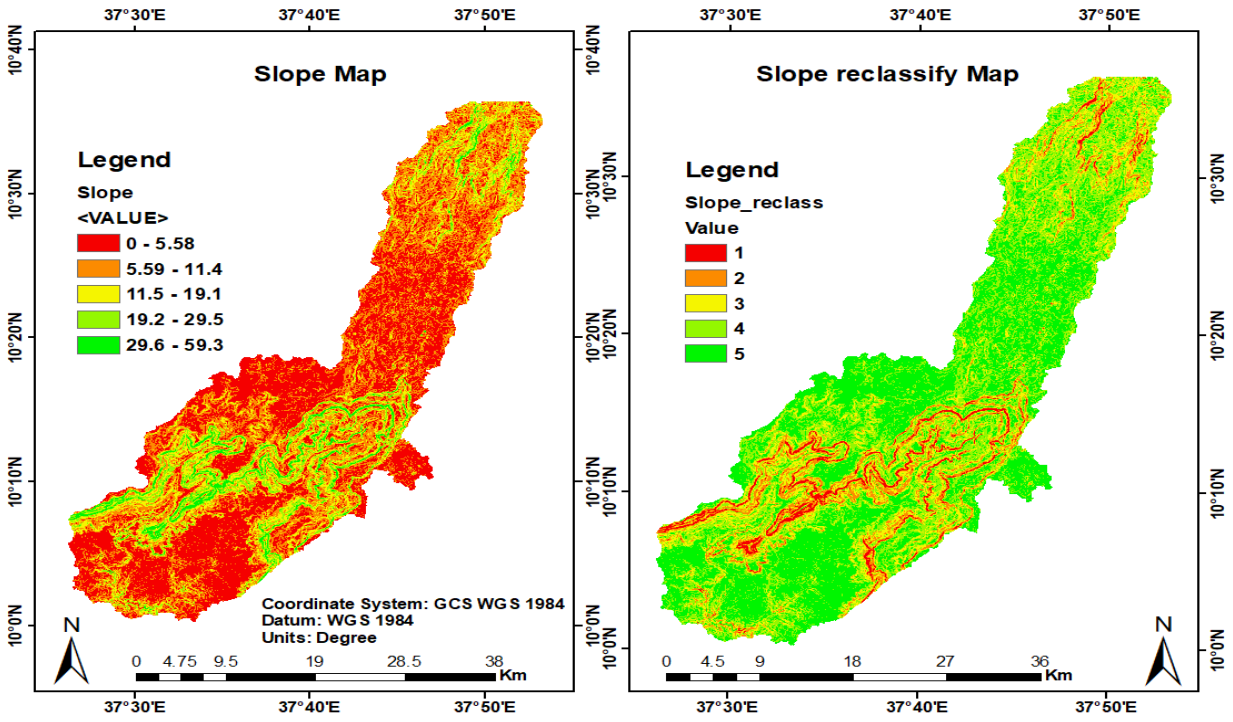


Figure 3. Slope and slope reclassify map.

3.3.3. Precipitation

Heavy rainfalls are one of the major causes of floods. Floods are associated with extremes in rainfall, any water that cannot immediately seep into the ground flows down slope as runoff. The

amount of runoff is related to the amount of rain a region experiences. The level of water in rivers or lakes rises due to heavy rain falls. When the level of water rises above the river banks or dams, the water starts overflowing, this causes floods *(Nicholls, 2001).* The amount of rainfall in mm which was derived from the map of average annual precipitation totals. In addition, heavy rainfall from the upstream point in a short period of time generally has a high potential for maximum flood events.

Areas having high annual rainfall are assumed to hold high potential of flooding. The precipitation raster layer were reclassified into five classes, in the reclassification process an area with higher rainfall, there is very highly affected by flood and then ranked as class 5. Following the very high hazard 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(in figure 4).

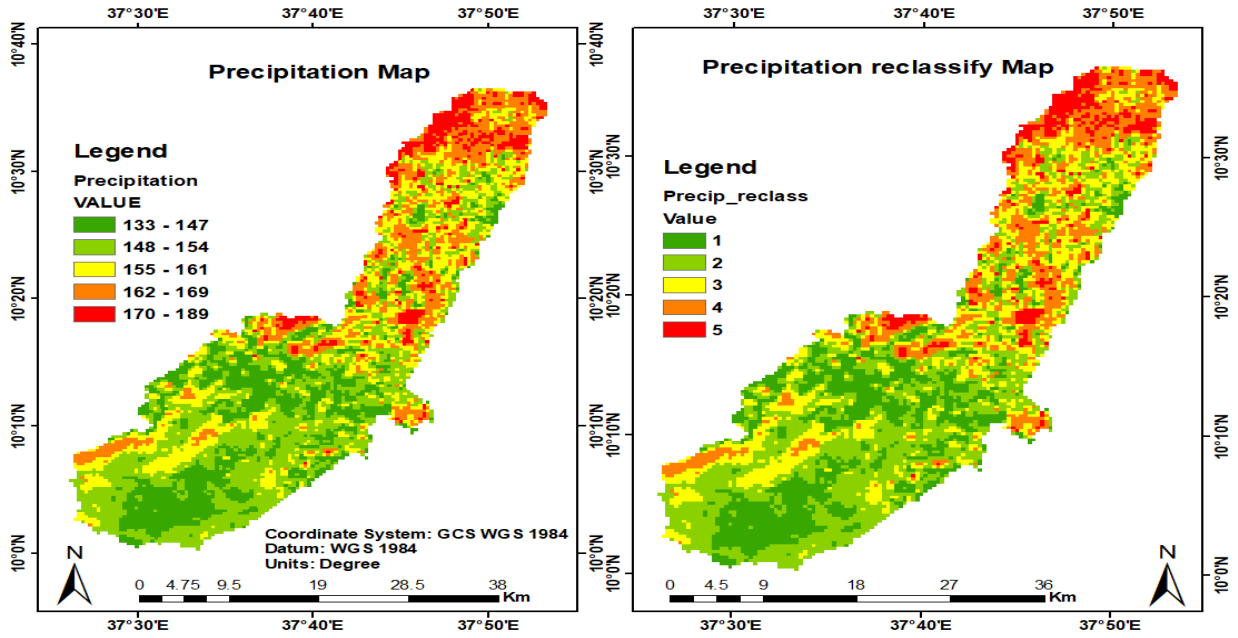


Figure 4. Precipitation and precipitation reclassify map

3.3.4. Distance to river

The distance from the river is one of the factors to determine the flood risk area; it was situated near river bank due to overflowing water *(Ali, Parvin et al. 2020)* and to obtain these distances, the Euclidean Distance tool was used in the Spatial Analyst Tools in ArcGIS. The closer the distance to the river's original flow, the greater the degree of danger. Generally, distance is

measured above the mouth of the stream or above the confluence. Any land area located far away from the mouth of the stream or its confluence is profiled as less risk zone while an area lying near the stream confluence is regarded as more flood risk area. The reclassification was based on assigning a value of 1 to areas farthest from streams (in figure 5).

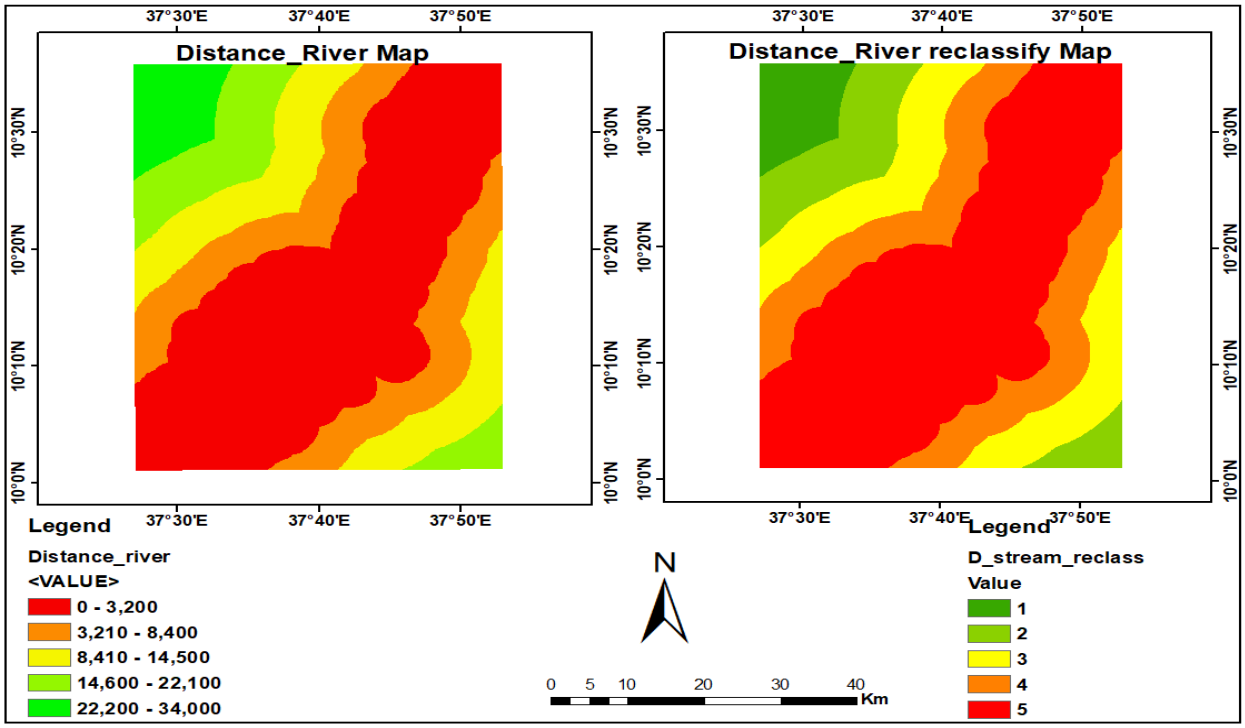


Figure 5. Distance to river and Distance to river reclassify map.

3.3.5. Drainage Density

The drainage density was determined by the ratio of the total length of the stream segments in the given watershed to the total area of the given watershed. Drainage is an important to control the flood hazard as its densities denote the nature of the water. This means that the higher the density, the higher the catchment area to flooding, resulting inundation at the lower grounds *(Strahler, 1999).* From DEM the study area can be clipped and stream network is done using the spatial analysis hydrology tool and use this as drainage network which is easy and can generate more accurate network of drainage. After this drainage density has to be calculated from the drainage map we get from the DEM.

This is done using the table in field calculator.

$$\text{Drainage Density} = \frac{L}{A} \qquad \text{Equation (7)}$$

Where L is the length of the drainage network and

A is the area of the drainage covers.

After drainage density calculation classification was done using the equal interval method of classification. This classification is done in five classes and the values are reversed because the higher the drainage density the higher the flood was done due to this the value is reversed to get the right classification. The drainage density layer was further reclassified in five sub-groups using the standard classification Schemes (Figure 6). Areas with very high drainage density are categorized as higher rank because of an area with a higher drainage density is very highly affected by flood and those with very low drainage density were categorized as lower rank because an area with a lower drainage density is very lowly affected by flood as depicted in the (Table 5).

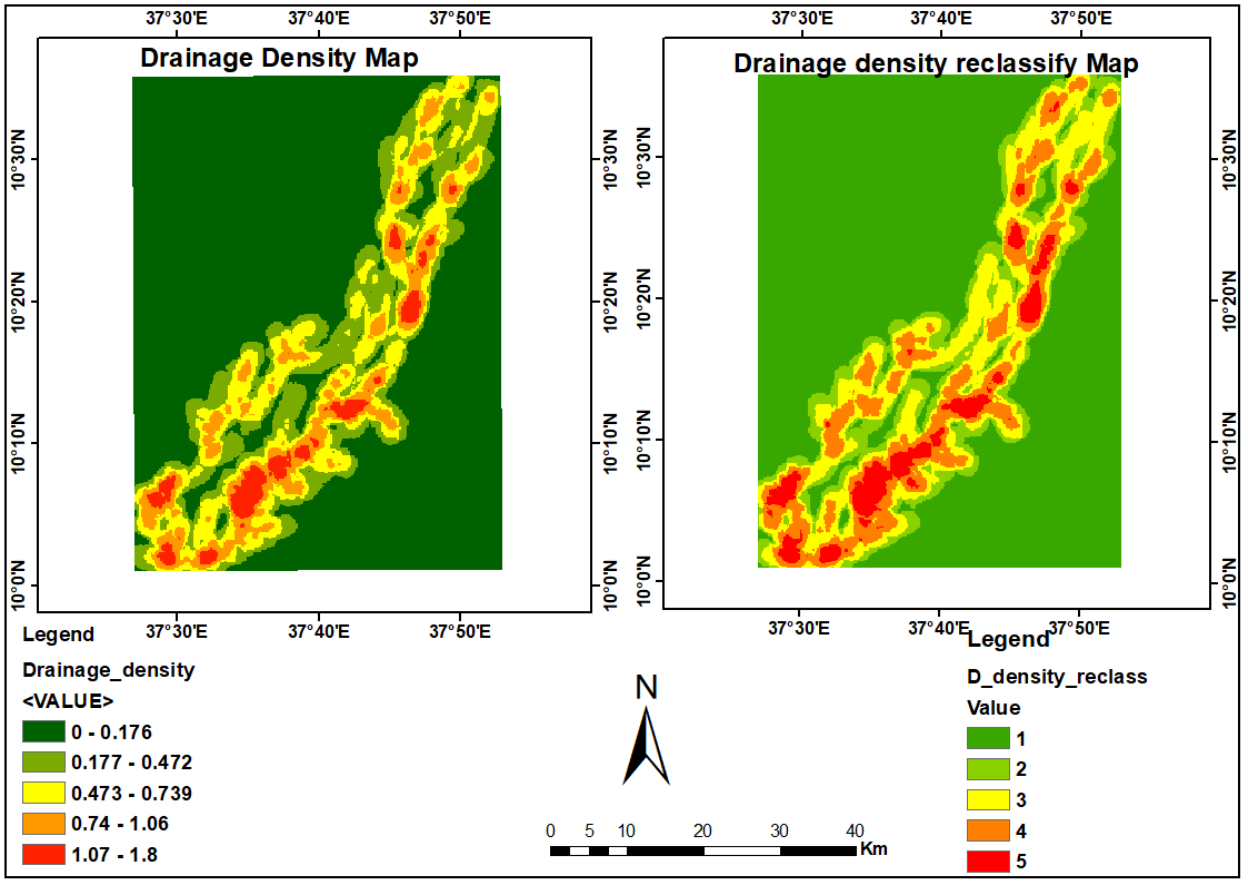


Figure 6. Drainage density and Drainage density reclassify map.

3.3.6. Land Use Land Cover

LULC is the primary driver in changing the landscape of a specific area. LULC map has been extracted from Landsat 8, year 2023 of Chemoga watershed. Using supervised classification has been done on the image processing software (QGIS) by Semi classification plugin. These classification in five classes, such as Agricultural land, Settlement, Bare land, Forest and Water bodies were identified. The reclassification process based on the highest coverage area (settlement) there is very highly affected by flood and then ranked as class 5. Following the high hazard agricultural land class, there is a class high ranked as class 4, bare land moderate ranked as class 3, forest, low ranked as class 2 and water body, very low ranked as class 1 (Figure 7).

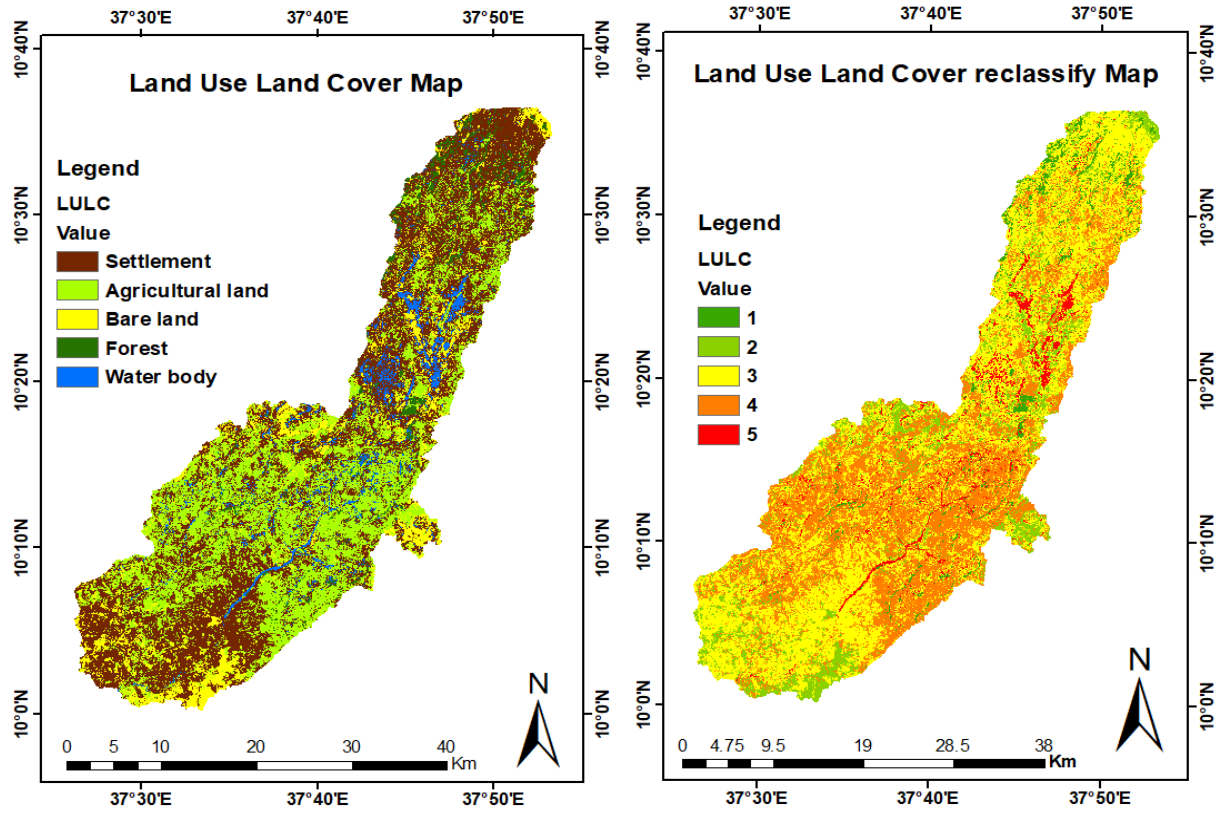


Figure 7. Land use land cover and Land use land cover reclassify map.

3.3.7. Soil Type

Although there is a wide range of soil types, the soil factor of the Chemoga Watershed was derived from the FAO standard classification of Ethiopian soil. These five major soil types were converted into raster and reclassified based on the flood generating capacity. The soil has a very high capacity

to generate a very high flood rate is ranked as class 5, high ranked as class 4, moderate ranked as class 3, low ranked as class 2 and very low ranked as class 1. The order of soil based on the typical flood risk from highest to lowest: Vertisols, including Pellic Vertisols, have a high clay content and tend to swell and crack when dry and hold large amounts of water when wet. This can lead to waterlogging and a significant flood risk, especially in areas of heavy rainfall or poor drainage.

Eutric are fertile and have good moisture retention but can also suffer from waterlogging during heavy rains, increasing the flood risk in areas with poor drainage or excessive rainfall. Dystric are typically well-drained, but under certain conditions, they can still become waterlogged, especially in areas with heavy or prolonged rainfall. The risk of flooding is lower compared to Eutric, but still significant in the right conditions. Chromic Luvisols have a more balanced texture, with good fertility and a relatively moderate drainage capacity. Rendzinas are shallow, well-drained soils, and Lithosols tend to be rocky and fast-draining. These properties help reduce the risk of flooding. Rendzinas are typically less susceptible to waterlogging, so they present the lowest flood risk among the listed (Figure 8).

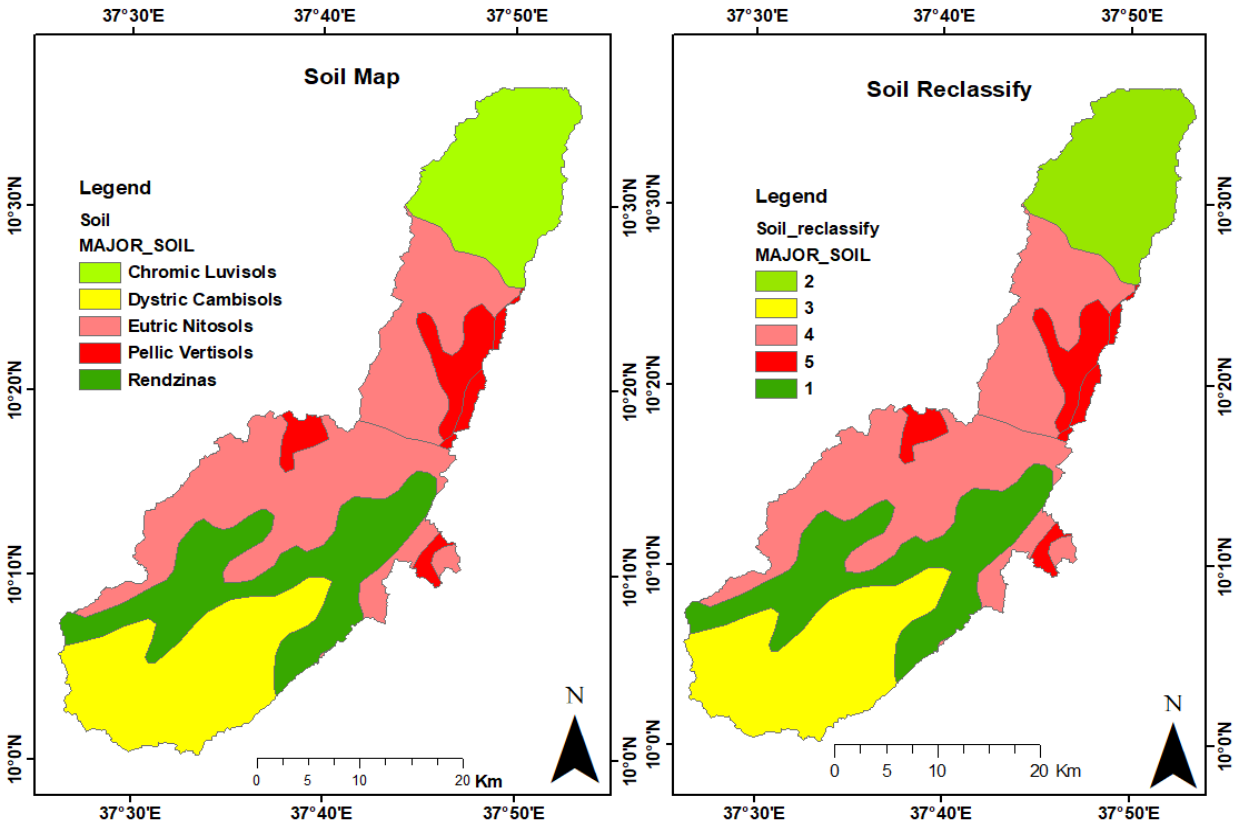


Figure 8. Soil and soil reclassify map

3.3.8. Distance to road

Distance to road is considered a factor contributing to flooding because roads, particularly when poorly designed or maintained, can act as boundaries to water flow, causing runoff to accumulate and potentially flood nearby areas, especially when located close to a road; essentially, the closer a location is to a road, the higher the potential for flooding due to improper drainage. The reclassification was based on assigning a value of 1 to areas farthest from road (Figure 9).

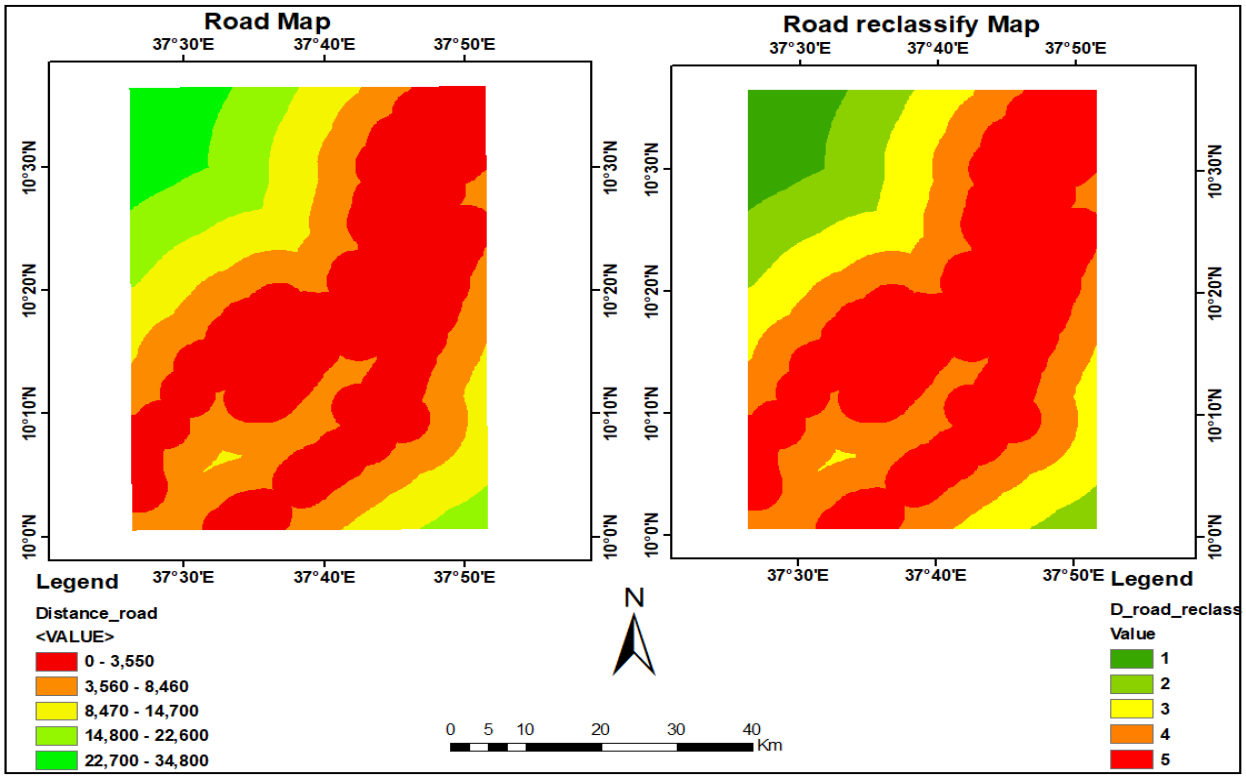


Figure 9. Distance to road and Distance to road reclassify map

Flood risk map showing the spatial distribution of flood risk along with its strength level, ranging from very high to very low risk *(Rincón, Khan et al. 2018)* . The Analytic Hierarchy Process (AHP) proposed by Saaty is one of the most common MCDM methods, and it has been widely applied to solve decision-making problems related to water resources. The purpose of AHP is providing decision makers with the decision, among different alternatives and criteria that best suits their goal. This method compares two criteria at a time through a pairwise comparison matrix, in which values of relative importance from one criterion over another criterion are assigned.

AHP, developed by Saaty in 1990, is one of the several criteria weighting methods of MCDM. Based on experts and literatures evaluate this method allows comparing two criteria at a time through a pairwise comparison matrix in which the values of relative importance from one criterion over another criterion are assigned. The standardized scale of relative importance ranges between 1 and 9, where 1 is equal importance, and 9 is extreme importance.

Table 4. Saaty's (1990) scale for weight assignment

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance

Note: 2, 4, 6 and 8 intermediate value and 1/3, 1/5, 1/7 and 1/9 inverse computation.

All the selected factors had not an equal contribution to the delineation of the flood hazard zone, due to these reasons the factors were rated and ranked in the Analytical hierarchical process (AHP) using the pairwise comparison matrix for the final spatial weighted overlay analysis of all factors to generate the final flood risk map of the present study.

Table 5. Weights of sub-classes using AHP comparison matrix

S. No	Parameter	Sub class	Risk Level	Rank	Weight (%)
1	Elevation (m)	889 – 1470	Very high	5	19
		1470 - 1941	High	4	
		1941 – 2342	Moderate	3	
		2342 – 2870	Low	2	
		2870 – 3814	Very low	1	
2	Slope	0 - 5.58	Very high	5	12
		5.59 - 11.4	High	4	
		11.5 - 19.1	Moderate	3	
		19.2 - 29.5	Low	2	

		29.6 – 59.3	Very low	1	
3	Precipitation	127 - 139	Very low	1	20
		139 - 146	Low	2	
		146 - 155	Moderate	3	
		155 - 166	High	4	
		166 - 190	Very high	5	
4	Distance to river	0 - 6,770	Very high	5	11
		6,780 - 13,500	High	4	
		13,600 - 20,300	Moderate	3	
		20,400 - 27,100	Low	2	
		27,200 - 33,900	Very low	1	
5	Distance to road	0 - 6,970	Very high	5	10
		6,980 - 13,900	High	4	
		14,000 - 20,900	Moderate	3	
		21,000 - 27,900	Low	2	
		28,000 - 34,800	Very low	1	
6	Drainage density	0 - 0. 176	Very low	1	5
		0.177 - 0.472	Low	2	
		0.473 - 0.739	Moderate	3	
		0.74 - 1.06	High	4	
		1.07 – 1.8	Very high	5	
7	LULC	Forest	Very low	1	12
		Bare land	Low	2	
		Agricultural land	Moderate	3	
		Settlement	High	4	
		Water body	Very high	5	
8	Soil	Rendzinas	Very low	1	11
		Chromic	Low	2	
		Dystric	Moderate	3	
		Eutric	High	4	
		Pellic	Very high	5	

100%

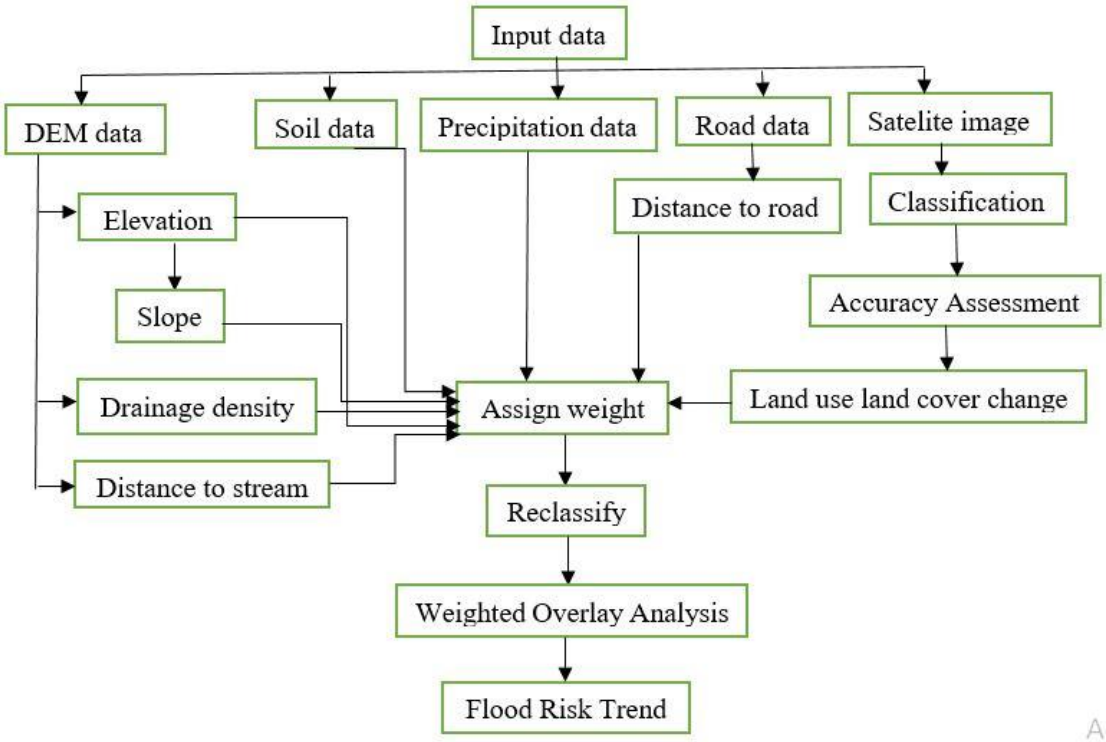


Figure 10. Methodology of flow chart

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. The result of land use land cover classification map

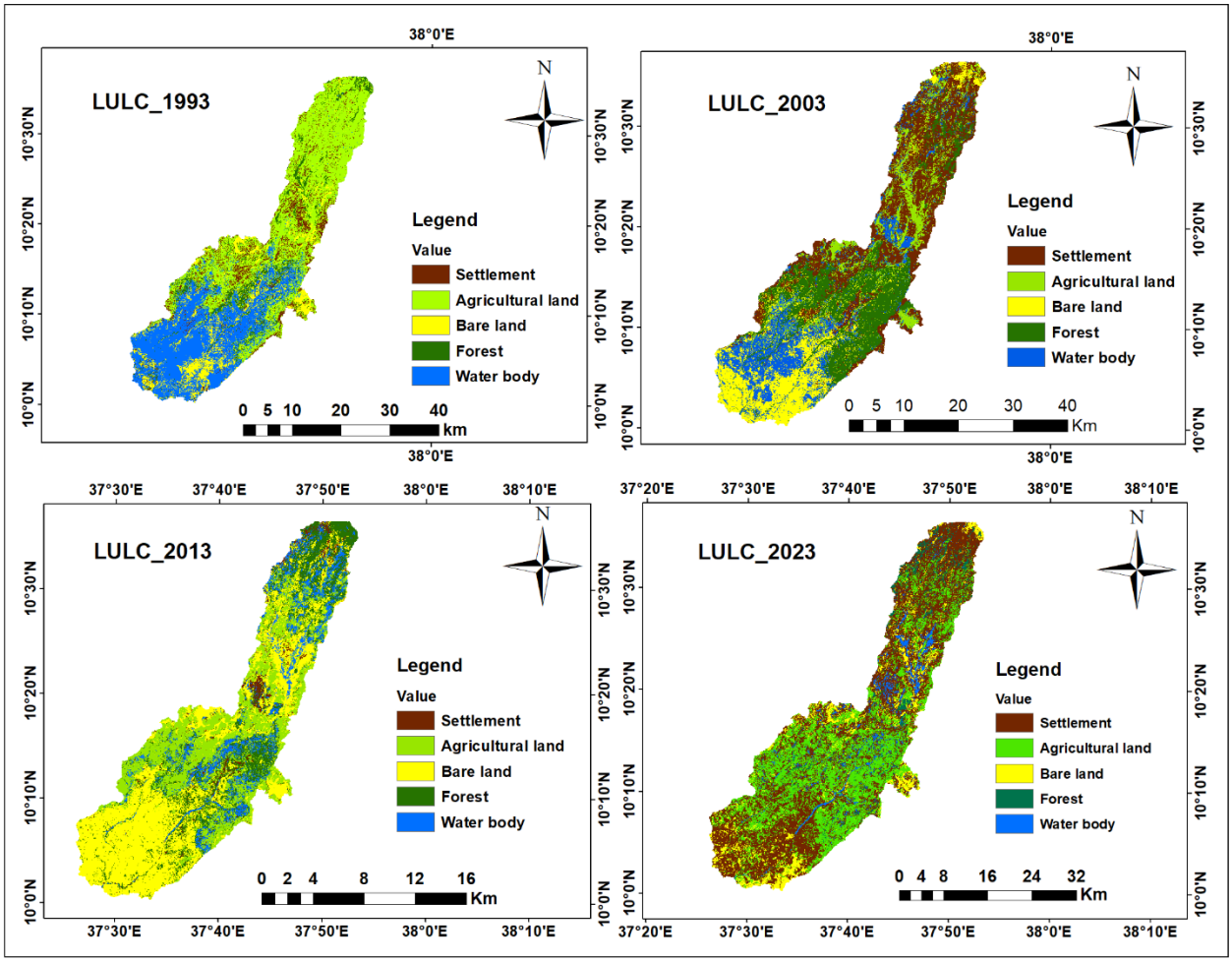


Figure 11. Classified LULC map of Chemoga watershed 1993, 2003, 2013 and 2023

Table 6. Area coverage of each classified LULC in hectare and percent

LULC Class	Year 1993		Year 2003		Year 2013		Year 2023	
	Area ha	%	Area ha	%	Area ha	%	Area ha	%
Settlement	10051.29	8.61	34482.15	29.52	3780.72	3.24	12412.53	16.50

Agricultural	48529.71	41.56	15250.86	13.06	31374.27	26.86	40748.13	54.14
Bare land	13317.21	11.40	20698.92	17.72	47881.26	40.99	12351.87	16.41
Forest	9244.17	7.92	27486.45	23.53	21377.34	18.29	4635.9	6.16
Water body	35632.35	30.51	18901.44	16.18	12412.53	10.62	5113.53	6.79
Total	116,774.73	100	116,819.8	100	116,826.12	100	75,261.96	100

The band processing (classification), the year 1993, the coverage area of land use land cover classification from highest to lowest Agricultural land 48,529.71 ha or 41.56%, Water body 35,632.35 ha or 30.51%, Bare land 13,317.21 ha or 11.40%, Settlement 10,051.29 ha or 8.61% and Forest 9,244.17 ha or 7.92 % respectively. The year 2003, the coverage area of land use land cover classification from highest to lowest Settlement 34,482.15 ha or 29.52 %, Forest 15250.86 ha or 23.53 %, Bare land 20,698.92 ha or 17.72 %, Water body 18,901.44 ha or 16.18 % and Agricultural land 15250.86 ha or 13.06%. Year 2013, the coverage area of land use land cover classification from highest to lowest Bare land 47881.26 ha or 40.99%, Agricultural land 31374.27 ha or 26.86%, Forest 21377.34 ha or 18.29 %, Water body 12412.53 ha or 10.62 % and Settlement 3780.72 ha or 3.24 %. In the year 2023, the coverage area of land use land cover classification from highest to lowest Agricultural land 40,748.13 ha or 54.14%, Settlement 12,412.53 ha or 16.50 %, Bare land 12,351.87 ha or 16.41 %, Water body 5,113.53ha or 6.79 % and Forest 4635.9 ha or 6.16%.

4.2. The result of Accuracy assessment

Table 7. Accuracy Assessment of classification in 1993

Classification in 1993	Settlement	Agricultural Land	Bare Land	Forest	Water body	Total Row	User Accuracy (%)
Settlement	9734	1886	101	97	844	12,662	77
Agricultural land	194	43058	113	275	707	44,347	97
Bare land	59	1599	12769	150	857	15,434	83
Forest	37	995	115	8564	582	10,293	83

Water body	26	990	219	158	32643	34,036	96
Total column	10,050	48,528	13,317	9,244	35,633	116,772	87.2
Producer Accuracy (%)	97	89	96	93	92	93.4	91.4

Table 8. Accuracy Assessment of classification in 2003

Classification in 2003	Settlement	Agricultural Land	Bare Land	Forest	Water body	Total Row	User Accuracy (%)
Settlement	31253	231	161	386	209	32240	96.93
Agricultural land	1002	14601	229	457	734	17023	85.77
Bare land	611	57	19569	866	702	21805	89.75
Forest	729	98	310	25375	222	26454	95.92
Water body	887	264	430	403	17035	19019	89.57
Total column	34482	15251	20699	27487	18902	116541	91.59
Producer Accuracy (%)	90.64	95.74	94.54	92.32	90.12	92.67	92.53

Table 9. Accuracy Assessment of classification in 2013

Classification in 2013	Settlement	Agricultural Land	Bare Land	Forest	Water body	Total Row	User Accuracy (%)
Settlement	5999	893	631	436	279	8238	72.82
Agricultural land	85	27580	376	342	280	28663	96.22
Bare land	118	615	44688	366	126	45913	97.33
Forest	110	686	800	19609	445	21650	90.57
Water body	74	517	163	440	11159	12353	90.33

Total column	6386	30291	46658	21193	12289	116817	89.45
Producer Accuracy (%)	93.94	91.05	95.78	92.53	90.80	92.82	93.34

Table 10. Accuracy Assessment of classification in 2023

Classification in 2023	Settlement	Agricultural Land	Bare Land	Forest	Water body	Total Row	User Accuracy (%)
Settlement	49635	1369	162	61	70	51297	96.76
Agricultural land	1566	37992	129	18	40	39745	95.59
Bare land	1238	597	12046	4	11	13896	86.69
Forest	485	114	3	4526	14	5142	88.02
Water body	1024	676	13	26	4978	6717	74.11
Total column	53948	39745	12253	4635	5113	116797	88.24
Producer Accuracy (%)	92.0	93.24	98.31	97.65	97.36	95.71	93.48

4.3. The result of Land use land cover changes

Table 11. Land use land cover changes of 1993 and 2003 in hectare

LULC Change	Settlement	Agricultural Land	Bare Land	Forest	Water body	Total
Settlement	6848.1	887.6	830.9	891.8	577.1	10,035.5
Agricultural	23599.9	7401.7	2041.0	11949.1	3490.7	48,482.4
Bare	2113.7	2338.9	5368.6	1917.2	1568.2	13,306.6
Forest	939.5	2854.6	1255.2	3374.2	815.4	9,238.9
Water body	903.9	1759.1	11173.9	9340.3	12442.6	35,619.8
Total	34,405.1	15,241.9	20,669.6	27,472.6	18,894	116,683.2

Table 12. Land use land cover changes of 2003 and 2013 in hectare.

LULC Change	Settlement	Agricultural Land	Bare Land	Forest	Water body	Total
Settlement	1758.3	15744.7	8362.5	5742.1	2818.7	34,426.3
Agricultural	407.6	1828.9	9236.1	2248.4	1521.8	15,242.8
Bare	351.8	2012.0	14587.9	3361.4	378.4	20,691.5
Forest	393.4	10754.3	2598.6	7229.8	6502.2	27,478.3
Water body	867.3	991.0	13066.6	2781	1186.5	18,892.4
Total	3,778.4	31,330.9	47,851.7	21362.7	12,407.6	116,731.3

Table 13. Land use land cover changes of 2013 and 2023 in hectare

LULC Change	Settlement	Agricultural Land	Bare Land	Forest	Water body	Total
Settlement	2303.5	515.4	178.8	375.4	402.8	3,775.9
Agricultural	10832.1	17261.7	2350.7	436.9	431.8	31,313.2
Bare	25014	11949.9	8602.8	456.7	1826.4	47,849.8
Forest	11379.7	6309.2	1082.8	1751.7	843.5	21,366.9
Water body	4372.2	4693.6	128.6	1605.2	1607.4	12,407
Total	53901.5	40,729.8	12,343.7	4,625.9	5,111.9	116,712.8

4.4. The result of flood risk trend map

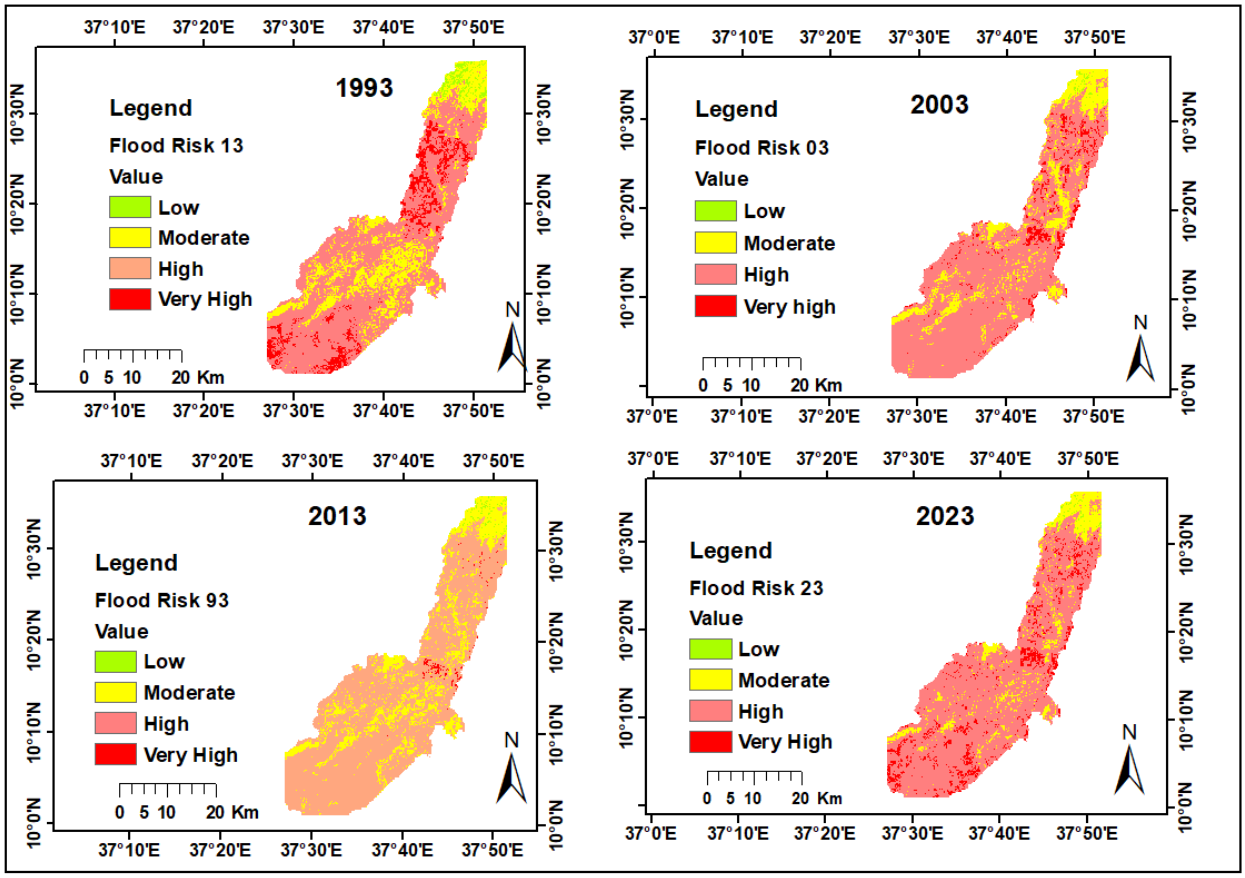


Figure 12. Flood risk trend of 1993, 2003, 2013 and 2023

Based on the analysis of Chemoga watershed flood risk trend map, in 1993 classes were classified as 2018.61 ha (1.83 %) low flood risk, 24750.09 ha (22.45 %) moderate flood risk, 73388.52 ha (66.56%) high flood risk and 10102.59 (9.16 %) very high flood risk. In 2003 classes were classified as 496.35 ha (0.45 %) low flood risk, 18699.93 ha (16.96 %) moderate flood risk, 85220.19 ha (77.29 %) high flood risk and 5843.34 ha (5.3 %) very high flood risk. In 2013 classes were classified as 600.12 ha (0.54 %) low flood risk, 23794.74 ha (21.58 %) moderate flood risk, 85003.65 ha (77.09%) high flood risk and 861.3 ha (0.78 %) very high flood risk. In 2023 classes were classified as 418.77 ha (0.38 %) low flood risk, 12910.14 ha (11.71 %) moderate flood risk, 87516.72 ha (79.37 %) high flood risk and 9414.18 ha (8.54 %) very high flood risk. So, from 1993 up to 2023, the highest percentage of flood risk was high flood risk and also the lowest percentage was low flood risk.

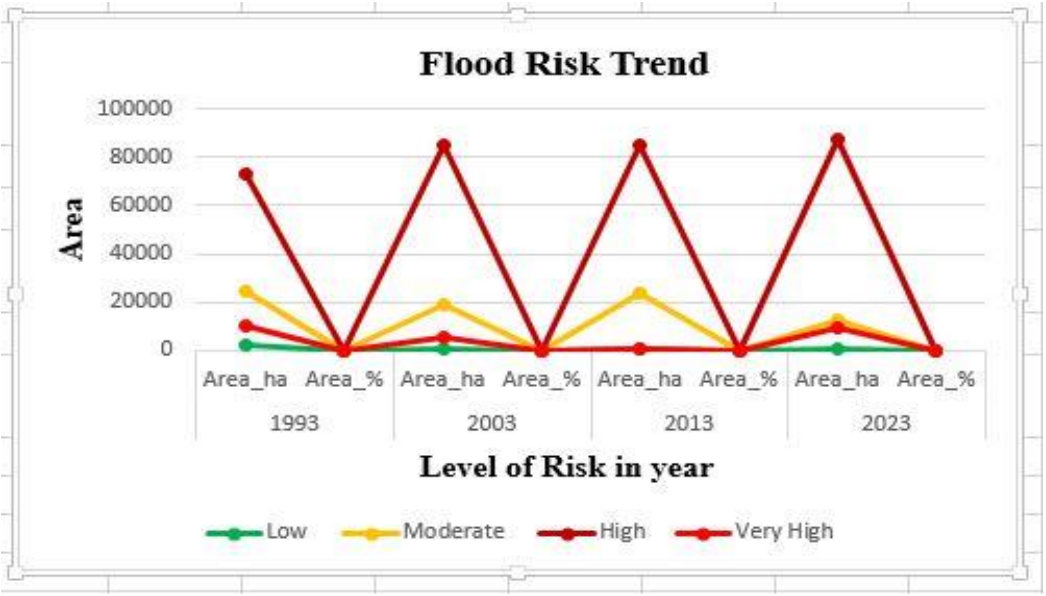


Figure 13. The graph of flood risk trend in 1993, 2003, 2013 and 2023

Table 14. Flood risk trend of 1993, 2003, 2013 and 2023 in hectare and percent

Flood Risk	1993		2003		2013		2023	
Trend	Area_ha	Area_%	Area_ha	Area_%	Area_ha	Area_%	Area_ha	Area_%
Low	2018.61	1.83	496.35	0.45	600.12	0.54	418.77	0.38
Moderate	24750.09	22.45	18699.93	16.96	23794.74	21.58	12910.14	11.71
High	73388.52	66.56	85220.19	77.29	85003.65	77.09	87516.72	79.37
Very High	10102.59	9.16	5843.34	5.3	861.3	0.78	9414.18	8.54
Total	110259.81	100	110259.81	100	110259.81	100	110259.81	100

4.5. Discussion

The significant changes of flood risk areas within the Chemoga Watershed due to different factors such as land use land cover changes (urbanization), topography (elevation and slope) and soil type. There were five types of land use land cover classification in the Chemoga Watershed i.e. settlement (urban), agricultural land, bare land, forest and water body. From these class integrated with the year 1993 to 2023, there was the increased agricultural land and settlement contrast to the other land use land cover classification. These findings can be used for flood risk management and planning in the watershed. GIS and remote sensing important for early flood prediction, disaster risk reduction, and land-use planning.

The importance of integrating spatial data and decision-making frameworks for effective flood management. MCDMA allows for evaluation of different risk factors, promoting up-to-date decisions regarding flood mitigation measures. This strength include preparation for better drainage systems, zoning measures to limit development in high-risk areas, and share in reforestation to reduce runoff.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The classified Land use land cover (LULC) performed on Quantum GIS (Q GIS) supervised classification and analysis was performed the Chemoga watershed Amhara region, Ethiopia. It was evaluated Land use land cover (LULC) changes of the year 1993 - 2003, 2003 – 2013 and 2013 – 2023) over the past 30 years. In the year 1993, the coverage area of land use land cover classification from highest to lowest Agricultural land 48,529.71 ha or 41.56%, Water body 35,632.35 ha or 30.51%, Bare land 13,317.21 ha or 11.40%, Settlement 10,051.29 ha or 8.61% and Forest 9,244.17 ha or 7.92 % respectively. In the year 2003, the coverage area of land use land cover classification from highest to lowest Settlement 34,482.15 ha or 29.52 %, Forest 15250.86 ha or 23.53 %, Bare land 20,698.92 ha or 17.72 %, Water body 18,901.44 ha or 16.18 % and Agricultural land 15250.86 ha or 13.06%.

In the year 2013, the coverage area of land use land cover classification from highest to lowest Bare land 47881.26 ha or 40.99%, Agricultural land 31374.27 ha or 26.86%, Forest 21377.34 ha or 18.29 %, Water body 12412.53 ha or 10.62 % and Settlement 3780.72 ha or 3.24 %. In the year 2023, the coverage area of land use land cover classification from highest to lowest Agricultural land 40,748.13 ha or 54.14%, Settlement 12,412.53 ha or 16.50 %, Bare land 12,351.87 ha or 16.41 %, Water body 5,113.53ha or 6.79 % and Forest 4635.9 ha or 6.16%.

The results of this analysis integrated spatial data and temporal changes of flood risk for prioritize effective flood management strategy, especially to identify the risk area by applied multi criteria decision making analysis evaluated different risk factors. As a result, Chemoga watershed Flood risk map classes in 1993 classes were classified as 2018.61 ha (1.83 %) low flood risk, 24750.09 ha (22.45 %) moderate flood risk, 73388.52 ha (66.56%) high flood risk and 10102.59 (9.16 %) very high flood risk. In 2003 classes were classified as 496.35 ha (0.45 %) low flood risk, 18699.93 ha (16.96 %) moderate flood risk, 85220.19 ha (77.29 %) high flood risk and 5843.34 ha (5.3 %) very high flood risk. In 2013 classes were classified as 600.12 ha (0.54 %) low flood risk, 23794.74 ha (21.58 %) moderate flood risk, 85003.65 ha (77.09%) high flood risk and 861. 3 ha (0.78 %)

very high flood risk. In 2023 classes were classified as 418.77 ha (0.38 %) low flood risk, 12910.14 ha (11.71 %) moderate flood risk, 87516.72 ha (79.37 %) high flood risk and 9414.18 ha (8.54 %) very high flood risk. So, from 1993 up to 2023, the highest percentage of flood risk was high flood risk and also the lowest percentage was low flood risk, so requires further action to reduce these risk.

5.2. Recommendation

- ✓ Local communities and stakeholders to gather understandings on flood impacts and improve of the Chemoga watershed against flooding.
- ✓ Not only governments but also others create a condition for early preparation and implementation of flooded areas protection measures, develop flood risk management and public awareness of the flood predictive prevention and make soil conservation, because flooding is one cause of soil erosion.
- ✓ Land use planning for better drainage systems, reduce informal settlement, soil conservation measures to reduce erosion and increase reforestation to reduce runoff, the risk measurement based on the risk level to limit or mitigate loss of live, resources and infrastructures.
- ✓ Future studies could further historical amount of flood events of these watershed flood over period.

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APPENDICES

Appendix 1. Land use land cover classification report in year 1993

Class	PixelSum	Percentage %	Area [metre^2]	ClassPixelSumPercentage %Area [metre^2]
-999	2390980	64.79304533	2151882000	-999239098064.79304532570227215188 2000
1	141283	3.828620826	127154700	11412833.828620826084365127154700
2	493044	13.36097426	443739600	249304413.360974261418143443739600
3	171855	4.657089898	154669500	31718554.657089898053753154669500
4	114628	3.106298338	103165200	41146283.106298337750462103165200
5	378390	10.25397135	340551000	537839010.253971350991009340551000

Appendix 2. Land use land cover classification report in year 2003

Class	PixelSum	Percentage %	Area [metre^2]	ClassPixelSumPercentage %Area [metre^2]
-999	2390980	64.79304533	2151882000	-999239098064.79304532570227215188 2000
1	358416	9.712696942	322574400	13584169.712696941612604322574400
2	189417	5.133001642	170475300	21894175.133001642196316170475300
3	242471	6.570709288	218223900	32424716.570709287893815218223900
4	297243	8.054972928	267518700	42972438.054972928149846267518700
5	211653	5.735573874	190487700	52116535.735573874445149190487700

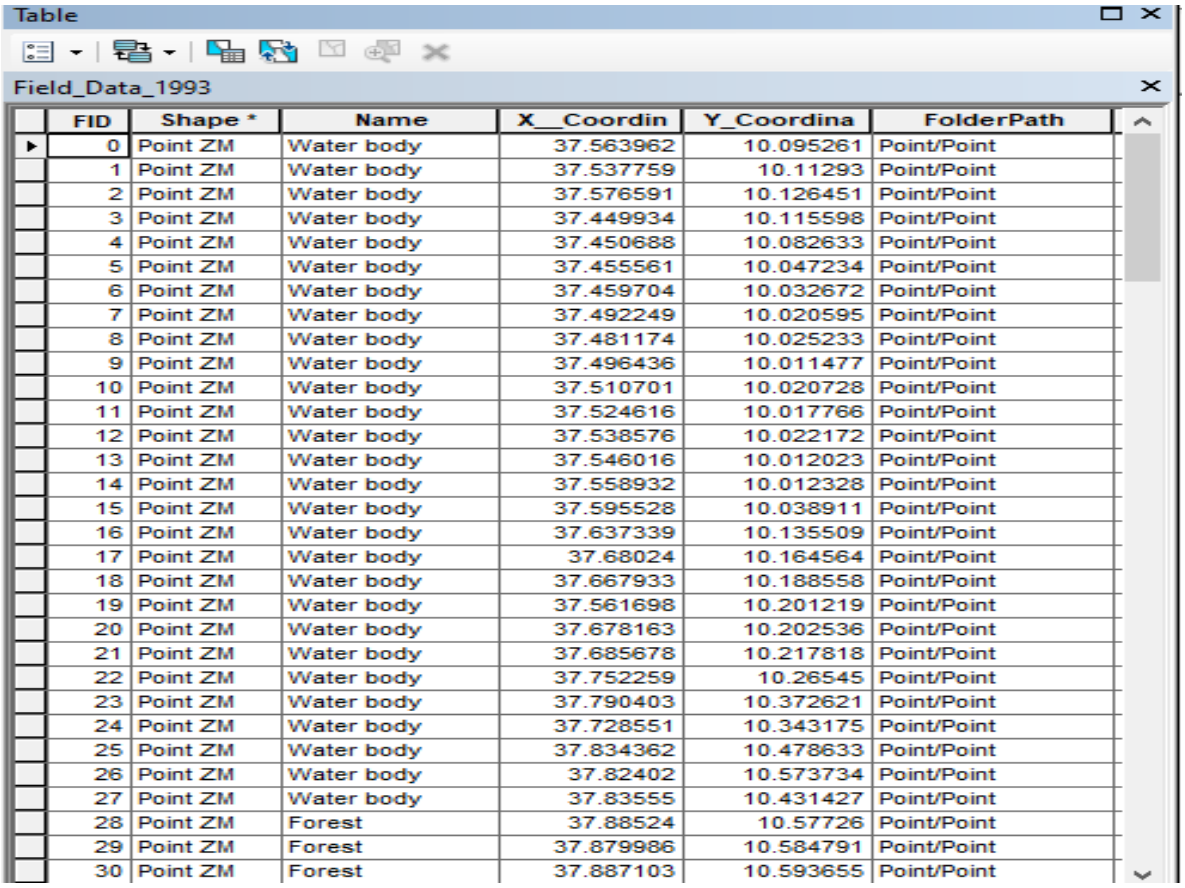
Appendix 3. Land use land cover classification report in year 2013

Class	PixelSum	Percentage %	Area [metr	ClassPixelSumPercentage %Area [metre^2]
1	60034	1.62685831	54030600	1600341.62685831043472145403 0600
2	332798	9.018476063	299518200	23327989.018476063498257299518200
3	523350	14.18223501	471015000	352335014.182235012926197471015000
4	243954	6.610897029	219558600	42439546.610897029413221955 8600
5	139054	3.768217269	125148600	51390543.768217268534326312514 8600

Appendix 4. Land use land cover classification report in year 2023

Class	PixelSum	Percentage %	Area [metre^2]	ClassPixelSumPercentage %Area [metre^2]
-999	2390990	64.79331632	2151891000	-999239099064.79331631519332151891000
1	570316	15.45496426	513284400	157031615.454964256486134513284400
2	441940	11.97610957	397746000	244194011.976109566471012397746000
3	154845	4.196136774	139360500	31548454.196136773815912139360500
4	57238	1.551089649	51514200	4572381.551089648743421851514200
5	74851	2.028383439	67365900	5748512.028383439290224567365900

Appendix 5. Accuracy Assessment of 1993



Table

Field_Data_1993

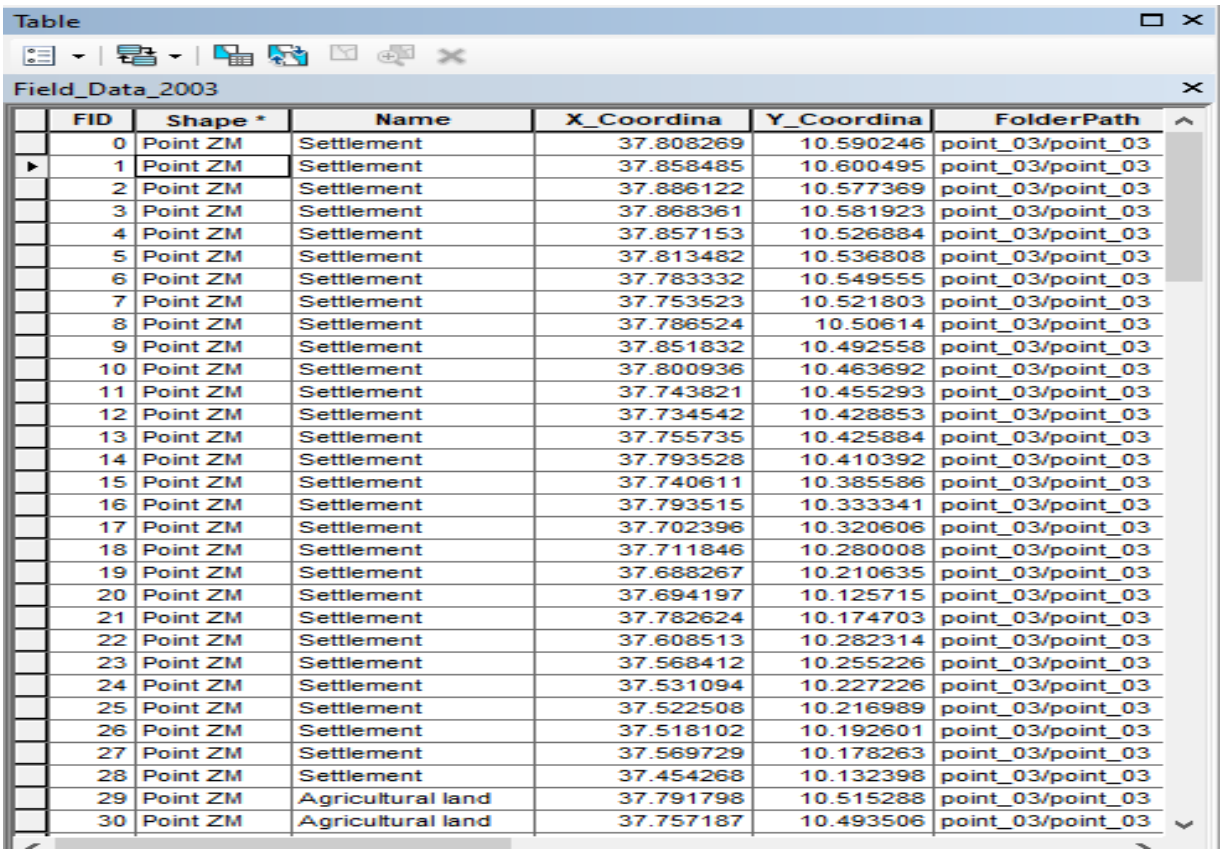
FID	Shape *	Name	X__Coordin	Y_Coordina	FolderPath
0	Point ZM	Water body	37.563962	10.095261	Point/Point
1	Point ZM	Water body	37.537759	10.11293	Point/Point
2	Point ZM	Water body	37.576591	10.126451	Point/Point
3	Point ZM	Water body	37.449934	10.115598	Point/Point
4	Point ZM	Water body	37.450688	10.082633	Point/Point
5	Point ZM	Water body	37.455561	10.047234	Point/Point
6	Point ZM	Water body	37.459704	10.032672	Point/Point
7	Point ZM	Water body	37.492249	10.020595	Point/Point
8	Point ZM	Water body	37.481174	10.025233	Point/Point
9	Point ZM	Water body	37.496436	10.011477	Point/Point
10	Point ZM	Water body	37.510701	10.020728	Point/Point
11	Point ZM	Water body	37.524616	10.017766	Point/Point
12	Point ZM	Water body	37.538576	10.022172	Point/Point
13	Point ZM	Water body	37.546016	10.012023	Point/Point
14	Point ZM	Water body	37.558932	10.012328	Point/Point
15	Point ZM	Water body	37.595528	10.038911	Point/Point
16	Point ZM	Water body	37.637339	10.135509	Point/Point
17	Point ZM	Water body	37.68024	10.164564	Point/Point
18	Point ZM	Water body	37.667933	10.188558	Point/Point
19	Point ZM	Water body	37.561698	10.201219	Point/Point
20	Point ZM	Water body	37.678163	10.202536	Point/Point
21	Point ZM	Water body	37.685678	10.217818	Point/Point
22	Point ZM	Water body	37.752259	10.26545	Point/Point
23	Point ZM	Water body	37.790403	10.372621	Point/Point
24	Point ZM	Water body	37.728551	10.343175	Point/Point
25	Point ZM	Water body	37.834362	10.478633	Point/Point
26	Point ZM	Water body	37.82402	10.573734	Point/Point
27	Point ZM	Water body	37.83555	10.431427	Point/Point
28	Point ZM	Forest	37.88524	10.57726	Point/Point
29	Point ZM	Forest	37.879986	10.584791	Point/Point
30	Point ZM	Forest	37.887103	10.593655	Point/Point
31	Point ZM	Forest	37.871807	10.591744	Point/Point
32	Point ZM	Forest	37.875351	10.606592	Point/Point
33	Point ZM	Forest	37.868121	10.60249	Point/Point
34	Point ZM	Forest	37.858484	10.608254	Point/Point
35	Point ZM	Forest	37.85452	10.59734	Point/Point
36	Point ZM	Forest	37.858792	10.566769	Point/Point
37	Point ZM	Forest	37.823179	10.566945	Point/Point
38	Point ZM	Forest	37.822921	10.548257	Point/Point
39	Point ZM	Forest	37.76275	10.535096	Point/Point
40	Point ZM	Forest	37.769823	10.518222	Point/Point
41	Point ZM	Forest	37.749194	10.517097	Point/Point
42	Point ZM	Forest	37.757889	10.490489	Point/Point
43	Point ZM	Forest	37.760207	10.454611	Point/Point
44	Point ZM	Forest	37.731591	10.440304	Point/Point
45	Point ZM	Forest	37.731683	10.424744	Point/Point
46	Point ZM	Forest	37.74091	10.416598	Point/Point
47	Point ZM	Forest	37.734466	10.399914	Point/Point
48	Point ZM	Forest	37.715346	10.248386	Point/Point
49	Point ZM	Forest	37.720035	10.199517	Point/Point
50	Point ZM	Forest	37.684048	10.146985	Point/Point
51	Point ZM	Forest	37.566592	10.034398	Point/Point
52	Point ZM	Forest	37.506268	10.02533	Point/Point
53	Point ZM	Forest	37.475337	10.032471	Point/Point
54	Point ZM	Forest	37.554062	10.011244	Point/Point
55	Point ZM	Forest	37.636914	10.093038	Point/Point
56	Point ZM	Forest	37.664203	10.132063	Point/Point
57	Point ZM	Forest	37.656343	10.171031	Point/Point
58	Point ZM	Bare land	37.591384	10.12086	Point/Point
59	Point ZM	Bare land	37.60746	10.088153	Point/Point
60	Point ZM	Bare land	37.531683	10.068985	Point/Point
61	Point ZM	Bare land	37.573301	10.060495	Point/Point

	62	Point ZM	Bare land	37.559831	10.022339	Point/Point
	63	Point ZM	Bare land	37.514999	10.015604	Point/Point
	64	Point ZM	Bare land	37.476014	10.036366	Point/Point
	65	Point ZM	Bare land	37.455032	10.104282	Point/Point
	66	Point ZM	Bare land	37.526897	10.115855	Point/Point
	67	Point ZM	Bare land	37.490995	10.152153	Point/Point
	68	Point ZM	Bare land	37.586872	10.158838	Point/Point
	69	Point ZM	Bare land	37.637692	10.159857	Point/Point
	70	Point ZM	Bare land	37.766472	10.174062	Point/Point
	71	Point ZM	Bare land	37.746419	10.196086	Point/Point
	72	Point ZM	Bare land	37.728972	10.23603	Point/Point
	73	Point ZM	Bare land	37.719772	10.259949	Point/Point
	74	Point ZM	Bare land	37.693893	10.291576	Point/Point
	75	Point ZM	Bare land	37.754041	10.29295	Point/Point
	76	Point ZM	Bare land	37.777162	10.31143	Point/Point
	77	Point ZM	Bare land	37.77858	10.335241	Point/Point
	78	Point ZM	Bare land	37.761479	10.382989	Point/Point
	79	Point ZM	Bare land	37.829589	10.594088	Point/Point
	80	Point ZM	Bare land	37.798879	10.382055	Point/Point
	81	Point ZM	Bare land	37.82742	10.605828	Point/Point
	82	Point ZM	Bare land	37.859983	10.553821	Point/Point
	83	Point ZM	Bare land	37.827498	10.550793	Point/Point
	84	Point ZM	Bare land	37.792312	10.553213	Point/Point
	85	Point ZM	Bare land	37.784333	10.560163	Point/Point
	86	Point ZM	Bare land	37.771	10.546059	Point/Point
	87	Point ZM	Bare land	37.761885	10.538654	Point/Point
	88	Point ZM	Bare land	37.771008	10.533337	Point/Point
	89	Point ZM	Agricultural land	37.650332	10.086039	Point/Point
	90	Point ZM	Agricultural land	37.636579	10.101435	Point/Point
	91	Point ZM	Agricultural land	37.666317	10.11041	Point/Point
	92	Point ZM	Agricultural land	37.708872	10.146534	Point/Point

	93	Point ZM	Agricultural land	37.586656	10.176437	Point/Point
	94	Point ZM	Agricultural land	37.487589	10.154639	Point/Point
	95	Point ZM	Agricultural land	37.518437	10.218619	Point/Point
	96	Point ZM	Agricultural land	37.55838	10.251166	Point/Point
	97	Point ZM	Agricultural land	37.581732	10.237968	Point/Point
	98	Point ZM	Agricultural land	37.610862	10.278855	Point/Point
	99	Point ZM	Agricultural land	37.673105	10.280211	Point/Point
	100	Point ZM	Agricultural land	37.667697	10.306766	Point/Point
	101	Point ZM	Agricultural land	37.643177	10.222394	Point/Point
	102	Point ZM	Agricultural land	37.697337	10.184452	Point/Point
	103	Point ZM	Agricultural land	37.71489	10.26524	Point/Point
	104	Point ZM	Agricultural land	37.756512	10.305189	Point/Point
	105	Point ZM	Agricultural land	37.777153	10.186858	Point/Point
	106	Point ZM	Agricultural land	37.739203	10.194879	Point/Point
	107	Point ZM	Agricultural land	37.782179	10.356895	Point/Point
	108	Point ZM	Agricultural land	37.710885	10.354737	Point/Point
	109	Point ZM	Agricultural land	37.774964	10.395253	Point/Point
	110	Point ZM	Agricultural land	37.850024	10.512297	Point/Point
	111	Point ZM	Agricultural land	37.819324	10.570832	Point/Point
	112	Point ZM	Agricultural land	37.866141	10.56511	Point/Point
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	117	Point ZM	Agricultural land	37.828589	10.447189	Point/Point
	118	Point ZM	Settlement	37.839154	10.596405	Point/Point
	119	Point ZM	Settlement	37.574253	10.033256	Point/Point
	120	Point ZM	Settlement	37.61087	10.053242	Point/Point
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	122	Point ZM	Settlement	37.720337	10.171967	Point/Point
	123	Point ZM	Settlement	37.756024	10.216761	Point/Point

	124	Point ZM	Settlement	37.704611	10.201747	Point/Point
	125	Point ZM	Settlement	37.773548	10.270043	Point/Point
	126	Point ZM	Settlement	37.71049	10.272286	Point/Point
	127	Point ZM	Settlement	37.637912	10.23541	Point/Point
	128	Point ZM	Settlement	37.532694	10.221633	Point/Point
	129	Point ZM	Settlement	37.520928	10.1947	Point/Point
	130	Point ZM	Settlement	37.50799	10.183667	Point/Point
	131	Point ZM	Settlement	37.478227	10.152039	Point/Point
	132	Point ZM	Settlement	37.486903	10.041838	Point/Point
	133	Point ZM	Settlement	37.610953	10.304784	Point/Point
	134	Point ZM	Settlement	37.644161	10.290108	Point/Point
	135	Point ZM	Settlement	37.713905	10.281686	Point/Point
	136	Point ZM	Settlement	37.771602	10.253423	Point/Point
	137	Point ZM	Settlement	37.771425	10.277739	Point/Point
	138	Point ZM	Settlement	37.755638	10.345388	Point/Point
	139	Point ZM	Settlement	37.793088	10.357334	Point/Point
	140	Point ZM	Settlement	37.748428	10.408467	Point/Point
	141	Point ZM	Settlement	37.767706	10.439602	Point/Point
	142	Point ZM	Settlement	37.857679	10.509701	Point/Point
	143	Point ZM	Settlement	37.850714	10.560848	Point/Point
	144	Point ZM	Settlement	37.884036	10.586869	Point/Point
	145	Point ZM	Settlement	37.84991	10.604878	Point/Point
	146	Point ZM	Settlement	37.812405	10.596754	Point/Point
	147	Point ZM	Settlement	37.760545	10.163477	Point/Point
	148	Point ZM	Settlement	37.806566	10.493618	Point/Point
	149	Point ZM	Settlement	37.742576	10.393938	Point/Point
	150	Point ZM	Settlement	37.762722	10.432678	Point/Point
	151	Point ZM	Settlement	37.75265	10.461348	Point/Point
	152	Point ZM	Settlement	37.808327	10.579941	Point/Point

Appendix 6. Accuracy Assessment of 2003



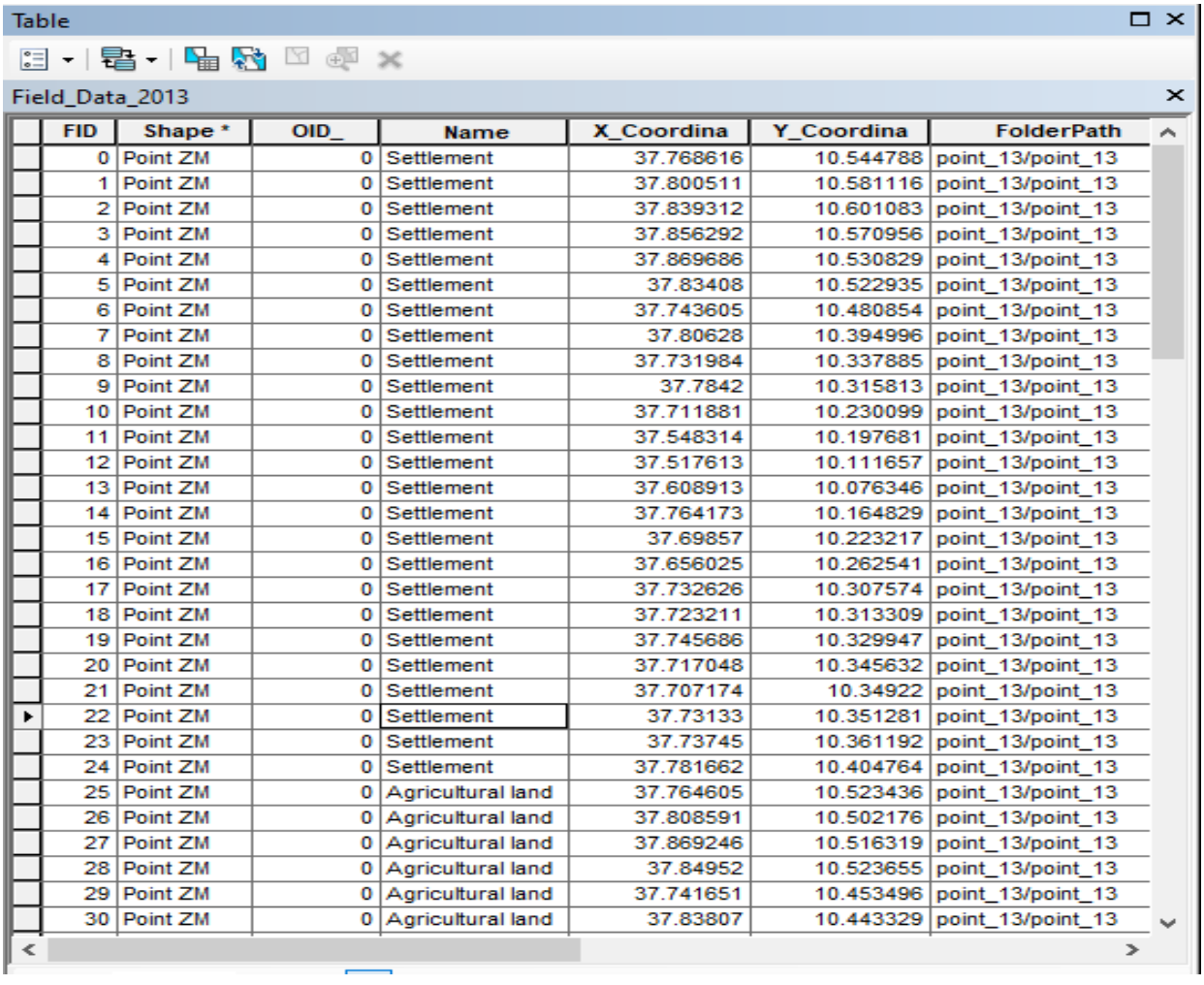
FID	Shape *	Name	X_Coordina	Y_Coordina	FolderPath
0	Point ZM	Settlement	37.808269	10.590246	point_03/point_03
1	Point ZM	Settlement	37.858485	10.600495	point_03/point_03
2	Point ZM	Settlement	37.886122	10.577369	point_03/point_03
3	Point ZM	Settlement	37.868361	10.581923	point_03/point_03
4	Point ZM	Settlement	37.857153	10.526884	point_03/point_03
5	Point ZM	Settlement	37.813482	10.536808	point_03/point_03
6	Point ZM	Settlement	37.783332	10.549555	point_03/point_03
7	Point ZM	Settlement	37.753523	10.521803	point_03/point_03
8	Point ZM	Settlement	37.786524	10.50614	point_03/point_03
9	Point ZM	Settlement	37.851832	10.492558	point_03/point_03
10	Point ZM	Settlement	37.800936	10.463692	point_03/point_03
11	Point ZM	Settlement	37.743821	10.455293	point_03/point_03
12	Point ZM	Settlement	37.734542	10.428853	point_03/point_03
13	Point ZM	Settlement	37.755735	10.425884	point_03/point_03
14	Point ZM	Settlement	37.793528	10.410392	point_03/point_03
15	Point ZM	Settlement	37.740611	10.385586	point_03/point_03
16	Point ZM	Settlement	37.793515	10.333341	point_03/point_03
17	Point ZM	Settlement	37.702396	10.320606	point_03/point_03
18	Point ZM	Settlement	37.711846	10.280008	point_03/point_03
19	Point ZM	Settlement	37.688267	10.210635	point_03/point_03
20	Point ZM	Settlement	37.694197	10.125715	point_03/point_03
21	Point ZM	Settlement	37.782624	10.174703	point_03/point_03
22	Point ZM	Settlement	37.608513	10.282314	point_03/point_03
23	Point ZM	Settlement	37.568412	10.255226	point_03/point_03
24	Point ZM	Settlement	37.531094	10.227226	point_03/point_03
25	Point ZM	Settlement	37.522508	10.216989	point_03/point_03
26	Point ZM	Settlement	37.518102	10.192601	point_03/point_03
27	Point ZM	Settlement	37.569729	10.178263	point_03/point_03
28	Point ZM	Settlement	37.454268	10.132398	point_03/point_03
29	Point ZM	Agricultural land	37.791798	10.515288	point_03/point_03
30	Point ZM	Agricultural land	37.757187	10.493506	point_03/point_03
31	Point ZM	Agricultural land	37.757639	10.536327	point_03/point_03
32	Point ZM	Agricultural land	37.772444	10.542417	point_03/point_03
33	Point ZM	Agricultural land	37.79628	10.552331	point_03/point_03
34	Point ZM	Agricultural land	37.832144	10.543776	point_03/point_03
35	Point ZM	Agricultural land	37.873438	10.603482	point_03/point_03
36	Point ZM	Agricultural land	37.871993	10.554096	point_03/point_03
37	Point ZM	Agricultural land	37.850781	10.548291	point_03/point_03
38	Point ZM	Agricultural land	37.848627	10.476306	point_03/point_03
39	Point ZM	Agricultural land	37.802825	10.411061	point_03/point_03
40	Point ZM	Agricultural land	37.723054	10.377201	point_03/point_03
41	Point ZM	Agricultural land	37.783222	10.368955	point_03/point_03
42	Point ZM	Agricultural land	37.711352	10.341112	point_03/point_03
43	Point ZM	Agricultural land	37.735753	10.270876	point_03/point_03
44	Point ZM	Agricultural land	37.762662	10.179519	point_03/point_03
45	Point ZM	Agricultural land	37.693064	10.152218	point_03/point_03
46	Point ZM	Agricultural land	37.662742	10.102305	point_03/point_03
47	Point ZM	Agricultural land	37.594481	10.113479	point_03/point_03
48	Point ZM	Agricultural land	37.556125	10.160397	point_03/point_03
49	Point ZM	Agricultural land	37.484963	10.085853	point_03/point_03
50	Point ZM	Agricultural land	37.497648	10.030629	point_03/point_03
51	Point ZM	Agricultural land	37.582539	10.28784	point_03/point_03
52	Point ZM	Agricultural land	37.621471	10.278907	point_03/point_03
53	Point ZM	Agricultural land	37.750673	10.311408	point_03/point_03
54	Point ZM	Agricultural land	37.763559	10.387581	point_03/point_03
55	Point ZM	Agricultural land	37.859275	10.508941	point_03/point_03
56	Point ZM	Agricultural land	37.88223	10.578857	point_03/point_03
57	Point ZM	Bare land	37.802986	10.578463	point_03/point_03
58	Point ZM	Bare land	37.818623	10.603583	point_03/point_03
59	Point ZM	Bare land	37.848266	10.606594	point_03/point_03
60	Point ZM	Bare land	37.878435	10.599822	point_03/point_03

	61	Point ZM	Bare land	37.874964	10.573916	point_03/point_03
	62	Point ZM	Bare land	37.848938	10.579561	point_03/point_03
	63	Point ZM	Bare land	37.786538	10.540959	point_03/point_03
	64	Point ZM	Bare land	37.845278	10.53996	point_03/point_03
	65	Point ZM	Bare land	37.819444	10.450873	point_03/point_03
	66	Point ZM	Bare land	37.818352	10.446637	point_03/point_03
	67	Point ZM	Bare land	37.76449	10.454234	point_03/point_03
	68	Point ZM	Bare land	37.729087	10.337849	point_03/point_03
	69	Point ZM	Bare land	37.783224	10.31252	point_03/point_03
	70	Point ZM	Bare land	37.588234	10.136733	point_03/point_03
	71	Point ZM	Bare land	37.604581	10.059649	point_03/point_03
	72	Point ZM	Bare land	37.551065	10.018148	point_03/point_03
	73	Point ZM	Bare land	37.45517	10.051933	point_03/point_03
	74	Point ZM	Bare land	37.447516	10.101929	point_03/point_03
	75	Point ZM	Bare land	37.48148	10.129778	point_03/point_03
	76	Point ZM	Bare land	37.532011	10.117899	point_03/point_03
	77	Point ZM	Bare land	37.627285	10.186023	point_03/point_03
	78	Point ZM	Bare land	37.573648	10.249746	point_03/point_03
	79	Point ZM	Bare land	37.554077	10.06675	point_03/point_03
	80	Point ZM	Bare land	37.728619	10.245687	point_03/point_03
	81	Point ZM	Bare land	37.670518	10.243093	point_03/point_03
	82	Point ZM	Bare land	37.699431	10.174848	point_03/point_03
	83	Point ZM	Forest	37.843989	10.46213	point_03/point_03
	84	Point ZM	Forest	37.850473	10.482257	point_03/point_03
	85	Point ZM	Forest	37.800479	10.496108	point_03/point_03
	86	Point ZM	Forest	37.864766	10.500987	point_03/point_03
	87	Point ZM	Forest	37.869125	10.544454	point_03/point_03
	88	Point ZM	Forest	37.822014	10.555935	point_03/point_03
	89	Point ZM	Forest	37.801562	10.501473	point_03/point_03
	90	Point ZM	Forest	37.868236	10.586204	point_03/point_03
	91	Point ZM	Forest	37.761165	10.491701	point_03/point_03

	92	Point ZM	Forest	37.784117	10.438066	point_03/point_03
	93	Point ZM	Forest	37.791345	10.371842	point_03/point_03
	94	Point ZM	Forest	37.747412	10.33947	point_03/point_03
	95	Point ZM	Forest	37.718599	10.329199	point_03/point_03
	96	Point ZM	Forest	37.70796	10.293352	point_03/point_03
	97	Point ZM	Forest	37.753103	10.261934	point_03/point_03
	98	Point ZM	Forest	37.755945	10.203438	point_03/point_03
	99	Point ZM	Forest	37.641958	10.129673	point_03/point_03
	100	Point ZM	Forest	37.637472	10.19596	point_03/point_03
	101	Point ZM	Forest	37.491263	10.156357	point_03/point_03
	102	Point ZM	Forest	37.470029	10.06635	point_03/point_03
	103	Point ZM	Forest	37.517999	10.116119	point_03/point_03
	104	Point ZM	Forest	37.530612	10.032925	point_03/point_03
	105	Point ZM	Forest	37.481122	10.027164	point_03/point_03
	106	Point ZM	Forest	37.649618	10.162648	point_03/point_03
	107	Point ZM	Water body	37.483403	10.028203	point_03/point_03
	108	Point ZM	Water body	37.454901	10.045656	point_03/point_03
	109	Point ZM	Water body	37.505441	10.051211	point_03/point_03
	110	Point ZM	Water body	37.546379	10.042281	point_03/point_03
	111	Point ZM	Water body	37.518412	10.081626	point_03/point_03
	112	Point ZM	Water body	37.567587	10.112013	point_03/point_03
	113	Point ZM	Water body	37.604248	10.040769	point_03/point_03
	114	Point ZM	Water body	37.451866	10.075213	point_03/point_03
	115	Point ZM	Water body	37.469931	10.098719	point_03/point_03
	116	Point ZM	Water body	37.45482	10.123769	point_03/point_03
	117	Point ZM	Water body	37.490691	10.135181	point_03/point_03
	118	Point ZM	Water body	37.535249	10.155999	point_03/point_03
	119	Point ZM	Water body	37.543961	10.13182	point_03/point_03
	120	Point ZM	Water body	37.594437	10.053055	point_03/point_03
	121	Point ZM	Water body	37.631614	10.168875	point_03/point_03
	122	Point ZM	Water body	37.546331	10.185274	point_03/point_03

123	Point ZM	Water body	37.674363	10.155532	point_03/point_03	
124	Point ZM	Water body	37.698957	10.229757	point_03/point_03	
125	Point ZM	Water body	37.5616	10.266676	point_03/point_03	
126	Point ZM	Water body	37.594327	10.279597	point_03/point_03	
127	Point ZM	Water body	37.627503	10.271587	point_03/point_03	
128	Point ZM	Water body	37.641912	10.294329	point_03/point_03	
129	Point ZM	Water body	37.68341	10.27627	point_03/point_03	
130	Point ZM	Water body	37.700237	10.303066	point_03/point_03	
131	Point ZM	Water body	37.730322	10.314646	point_03/point_03	
132	Point ZM	Water body	37.75645	10.304083	point_03/point_03	
133	Point ZM	Water body	37.79488	10.352013	point_03/point_03	
134	Point ZM	Water body	37.857341	10.539492	point_03/point_03	
135	Point ZM	Water body	37.752063	10.535924	point_03/point_03	
136	Point ZM	Water body	37.860546	10.506305	point_03/point_03	
137	Point ZM	Water body	37.814844	10.581124	point_03/point_03	
138	Point ZM	Water body	37.774151	10.525452	point_03/point_03	
139	Point ZM	Water body	37.76477	10.51994	point_03/point_03	
140	Point ZM	Water body	37.867647	10.593305	point_03/point_03	

Appendix 7. Accuracy Assessment of 2013



FID	Shape *	OID_	Name	X_Coordina	Y_Coordina	FolderPath
0	Point ZM	0	Settlement	37.768616	10.544788	point_13/point_13
1	Point ZM	0	Settlement	37.800511	10.581116	point_13/point_13
2	Point ZM	0	Settlement	37.839312	10.601083	point_13/point_13
3	Point ZM	0	Settlement	37.856292	10.570956	point_13/point_13
4	Point ZM	0	Settlement	37.869686	10.530829	point_13/point_13
5	Point ZM	0	Settlement	37.83408	10.522935	point_13/point_13
6	Point ZM	0	Settlement	37.743605	10.480854	point_13/point_13
7	Point ZM	0	Settlement	37.80628	10.394996	point_13/point_13
8	Point ZM	0	Settlement	37.731984	10.337885	point_13/point_13
9	Point ZM	0	Settlement	37.7842	10.315813	point_13/point_13
10	Point ZM	0	Settlement	37.711881	10.230099	point_13/point_13
11	Point ZM	0	Settlement	37.548314	10.197681	point_13/point_13
12	Point ZM	0	Settlement	37.517613	10.111657	point_13/point_13
13	Point ZM	0	Settlement	37.608913	10.076346	point_13/point_13
14	Point ZM	0	Settlement	37.764173	10.164829	point_13/point_13
15	Point ZM	0	Settlement	37.69857	10.223217	point_13/point_13
16	Point ZM	0	Settlement	37.656025	10.262541	point_13/point_13
17	Point ZM	0	Settlement	37.732626	10.307574	point_13/point_13
18	Point ZM	0	Settlement	37.723211	10.313309	point_13/point_13
19	Point ZM	0	Settlement	37.745686	10.329947	point_13/point_13
20	Point ZM	0	Settlement	37.717048	10.345632	point_13/point_13
21	Point ZM	0	Settlement	37.707174	10.34922	point_13/point_13
22	Point ZM	0	Settlement	37.73133	10.351281	point_13/point_13
23	Point ZM	0	Settlement	37.73745	10.361192	point_13/point_13
24	Point ZM	0	Settlement	37.781662	10.404764	point_13/point_13
25	Point ZM	0	Agricultural land	37.764605	10.523436	point_13/point_13
26	Point ZM	0	Agricultural land	37.808591	10.502176	point_13/point_13
27	Point ZM	0	Agricultural land	37.869246	10.516319	point_13/point_13
28	Point ZM	0	Agricultural land	37.84952	10.523655	point_13/point_13
29	Point ZM	0	Agricultural land	37.741651	10.453496	point_13/point_13
30	Point ZM	0	Agricultural land	37.83807	10.443329	point_13/point_13

31	Point ZM	0	Agricultural land	37.835559	10.470908	point_13/point_13
32	Point ZM	0	Agricultural land	37.778437	10.422789	point_13/point_13
33	Point ZM	0	Agricultural land	37.800372	10.369716	point_13/point_13
34	Point ZM	0	Agricultural land	37.800372	10.369716	point_13/point_13
35	Point ZM	0	Agricultural land	37.713032	10.36078	point_13/point_13
36	Point ZM	0	Agricultural land	37.751447	10.358496	point_13/point_13
37	Point ZM	0	Agricultural land	37.764196	10.319676	point_13/point_13
38	Point ZM	0	Agricultural land	37.709321	10.317794	point_13/point_13
39	Point ZM	0	Agricultural land	37.728172	10.280068	point_13/point_13
40	Point ZM	0	Agricultural land	37.76569	10.252719	point_13/point_13
41	Point ZM	0	Agricultural land	37.578206	10.28133	point_13/point_13
42	Point ZM	0	Agricultural land	37.634038	10.233051	point_13/point_13
43	Point ZM	0	Agricultural land	37.768958	10.197612	point_13/point_13
44	Point ZM	0	Agricultural land	37.680795	10.160399	point_13/point_13
45	Point ZM	0	Agricultural land	37.647042	10.099097	point_13/point_13
46	Point ZM	0	Agricultural land	37.516234	10.052578	point_13/point_13
47	Point ZM	0	Bare land	37.451989	10.118458	point_13/point_13
48	Point ZM	0	Bare land	37.546727	10.029026	point_13/point_13
49	Point ZM	0	Bare land	37.616605	10.102086	point_13/point_13
50	Point ZM	0	Bare land	37.554166	10.136801	point_13/point_13
51	Point ZM	0	Bare land	37.569926	10.214703	point_13/point_13
52	Point ZM	0	Bare land	37.75234	10.17847	point_13/point_13
53	Point ZM	0	Bare land	37.687148	10.2211	point_13/point_13
54	Point ZM	0	Bare land	37.583913	10.28935	point_13/point_13
55	Point ZM	0	Bare land	37.644152	10.302734	point_13/point_13
56	Point ZM	0	Bare land	37.715284	10.332566	point_13/point_13
57	Point ZM	0	Bare land	37.77771	10.308775	point_13/point_13
58	Point ZM	0	Bare land	37.745944	10.304528	point_13/point_13
59	Point ZM	0	Bare land	37.758878	10.393673	point_13/point_13
60	Point ZM	0	Bare land	37.810228	10.407505	point_13/point_13
61	Point ZM	0	Bare land	37.801081	10.438837	point_13/point_13

62	Point ZM	0	Bare land	37.7576	10.493096	point_13/point_13
63	Point ZM	0	Bare land	37.821338	10.475529	point_13/point_13
64	Point ZM	0	Bare land	37.78226	10.545714	point_13/point_13
65	Point ZM	0	Bare land	37.833635	10.605768	point_13/point_13
66	Point ZM	0	Bare land	37.855731	10.582167	point_13/point_13
67	Point ZM	0	4	37.864162	10.602853	point_13/point_13
68	Point ZM	0	4	37.818127	10.603994	point_13/point_13
69	Point ZM	0	4	37.825747	10.573339	point_13/point_13
70	Point ZM	0	4	37.777001	10.540878	point_13/point_13
71	Point ZM	0	4	37.820466	10.515525	point_13/point_13
72	Point ZM	0	4	37.844395	10.475577	point_13/point_13
73	Point ZM	0	4	37.777813	10.45278	point_13/point_13
74	Point ZM	0	4	37.734703	10.45261	point_13/point_13
75	Point ZM	0	4	37.823061	10.417775	point_13/point_13
76	Point ZM	0	4	37.793363	10.415414	point_13/point_13
77	Point ZM	0	4	37.790448	10.369106	point_13/point_13
78	Point ZM	0	Forest	37.740383	10.311135	point_13/point_13
79	Point ZM	0	Forest	37.727553	10.236279	point_13/point_13
80	Point ZM	0	Forest	37.640798	10.225355	point_13/point_13
81	Point ZM	0	Forest	37.746083	10.208097	point_13/point_13
82	Point ZM	0	Forest	37.647868	10.127896	point_13/point_13
83	Point ZM	0	Forest	37.624584	10.264648	point_13/point_13
84	Point ZM	0	Forest	37.524694	10.226842	point_13/point_13
85	Point ZM	0	Forest	37.590598	10.170558	point_13/point_13
86	Point ZM	0	Forest	37.57603	10.058554	point_13/point_13
87	Point ZM	0	Forest	37.512359	10.025276	point_13/point_13
88	Point ZM	0	Water body	37.480379	10.025789	point_13/point_13
89	Point ZM	0	Water body	37.506551	10.028004	point_13/point_13
90	Point ZM	0	Water body	37.551134	10.048368	point_13/point_13
91	Point ZM	0	Water body	37.523079	10.177498	point_13/point_13
92	Point ZM	0	Water body	37.624259	10.201747	point_13/point_13

	93	Point ZM	0	Water body	37.632068	10.199077	point_13/point_13
	94	Point ZM	0	Water body	37.673667	10.151234	point_13/point_13
	95	Point ZM	0	Water body	37.742996	10.198689	point_13/point_13
	96	Point ZM	0	Water body	37.64257	10.295475	point_13/point_13
	97	Point ZM	0	Water body	37.738723	10.261927	point_13/point_13
	98	Point ZM	0	Water body	37.752179	10.30521	point_13/point_13
	99	Point ZM	0	Water body	37.718019	10.337023	point_13/point_13
	100	Point ZM	0	Water body	37.781196	10.375173	point_13/point_13
	101	Point ZM	0	Water body	37.833058	10.427552	point_13/point_13
	102	Point ZM	0	Water body	37.798071	10.45935	point_13/point_13
	103	Point ZM	0	Water body	37.746061	10.511619	point_13/point_13
	104	Point ZM	0	Water body	37.859451	10.542106	point_13/point_13
	105	Point ZM	0	Water body	37.819329	10.584304	point_13/point_13
	106	Point ZM	0	Water body	37.884445	10.587196	point_13/point_13
	107	Point ZM	0	Water body	37.856723	10.602022	point_13/point_13
	108	Point ZM	0	Water body	37.829335	10.594289	point_13/point_13
	109	Point ZM	0	Water body	37.819472	10.538916	point_13/point_13
	110	Point ZM	0	Water body	37.58968	10.254998	point_13/point_13

Appendix 8. Accuracy Assessment of 2023

Table

Field_Data_2023

	FID	Shape *	Name	X_Coordina	Y_Coordina	FolderPath
▶	0	Point ZM	Water body	37.759721	10.454634	Point_23/Point_23
	1	Point ZM	Water body	37.730682	10.423782	Point_23/Point_23
	2	Point ZM	Water body	37.760066	10.409047	Point_23/Point_23
	3	Point ZM	Water body	37.805771	10.433695	Point_23/Point_23
	4	Point ZM	Water body	37.7929	10.396706	Point_23/Point_23
	5	Point ZM	Water body	37.789527	10.369075	Point_23/Point_23
	6	Point ZM	Water body	37.835891	10.42525	Point_23/Point_23
	7	Point ZM	Water body	37.852025	10.529001	Point_23/Point_23
	8	Point ZM	Water body	37.820836	10.569945	Point_23/Point_23
	9	Point ZM	Water body	37.856639	10.602191	Point_23/Point_23
	10	Point ZM	Water body	37.807963	10.556868	Point_23/Point_23
	11	Point ZM	Water body	37.737393	10.332113	Point_23/Point_23
	12	Point ZM	Water body	37.710615	10.34935	Point_23/Point_23
	13	Point ZM	Water body	37.684422	10.275958	Point_23/Point_23
	14	Point ZM	Water body	37.702839	10.213733	Point_23/Point_23
	15	Point ZM	Water body	37.777584	10.177206	Point_23/Point_23
	16	Point ZM	Water body	37.658314	10.171435	Point_23/Point_23
	17	Point ZM	Water body	37.609292	10.134388	Point_23/Point_23
	18	Point ZM	Water body	37.528618	10.135096	Point_23/Point_23
	19	Point ZM	Water body	37.530298	10.033237	Point_23/Point_23
	20	Point ZM	Water body	37.479462	10.024722	Point_23/Point_23
	21	Point ZM	Water body	37.57734	10.244679	Point_23/Point_23
	22	Point ZM	Water body	37.614469	10.29927	Point_23/Point_23
	23	Point ZM	Water body	37.712255	10.131488	Point_23/Point_23
	24	Point ZM	Forest	37.701794	10.132978	Point_23/Point_23
	25	Point ZM	Forest	37.665232	10.102695	Point_23/Point_23
	26	Point ZM	Forest	37.638566	10.109262	Point_23/Point_23
	27	Point ZM	Forest	37.489847	10.029528	Point_23/Point_23
	28	Point ZM	Forest	37.520428	10.117468	Point_23/Point_23
	29	Point ZM	Forest	37.526084	10.18621	Point_23/Point_23
	30	Point ZM	Forest	37.526789	10.22261	Point_23/Point_23

	31	Point ZM	Forest	37.542553	10.232903	Point_23/Point_23
	32	Point ZM	Forest	37.563057	10.237086	Point_23/Point_23
	33	Point ZM	Forest	37.586087	10.262675	Point_23/Point_23
	34	Point ZM	Forest	37.616336	10.29273	Point_23/Point_23
	35	Point ZM	Forest	37.630188	10.306559	Point_23/Point_23
	36	Point ZM	Forest	37.645699	10.288567	Point_23/Point_23
	37	Point ZM	Forest	37.673433	10.307767	Point_23/Point_23
	38	Point ZM	Forest	37.673433	10.307767	Point_23/Point_23
	39	Point ZM	Forest	37.698338	10.302199	Point_23/Point_23
	40	Point ZM	Forest	37.708851	10.325728	Point_23/Point_23
	41	Point ZM	Forest	37.73589	10.310408	Point_23/Point_23
	42	Point ZM	Forest	37.747198	10.341314	Point_23/Point_23
	43	Point ZM	Forest	37.755899	10.27741	Point_23/Point_23
	44	Point ZM	Forest	37.75948	10.257692	Point_23/Point_23
	45	Point ZM	Forest	37.637498	10.219068	Point_23/Point_23
	46	Point ZM	Forest	37.798423	10.45918	Point_23/Point_23
	47	Point ZM	Forest	37.776029	10.529749	Point_23/Point_23
	48	Point ZM	Forest	37.861029	10.541802	Point_23/Point_23
	49	Point ZM	Forest	37.812435	10.595933	Point_23/Point_23
	50	Point ZM	Forest	37.870774	10.599778	Point_23/Point_23
	51	Point ZM	Bare land	37.768423	10.177098	Point_23/Point_23
	52	Point ZM	Bare land	37.754328	10.214468	Point_23/Point_23
	53	Point ZM	Bare land	37.765893	10.249974	Point_23/Point_23
	54	Point ZM	Bare land	37.748456	10.310625	Point_23/Point_23
	55	Point ZM	Bare land	37.712414	10.330735	Point_23/Point_23
	56	Point ZM	Bare land	37.724611	10.386176	Point_23/Point_23
	57	Point ZM	Bare land	37.726608	10.403648	Point_23/Point_23
	58	Point ZM	Bare land	37.757312	10.399293	Point_23/Point_23
	59	Point ZM	Bare land	37.826277	10.472921	Point_23/Point_23
	60	Point ZM	Bare land	37.885421	10.585128	Point_23/Point_23
	61	Point ZM	Bare land	37.864619	10.601391	Point_23/Point_23

	62	Point ZM	Bare land	37.818021	10.604067	Point_23/Point_23
	63	Point ZM	Bare land	37.838161	10.574327	Point_23/Point_23
	64	Point ZM	Bare land	37.63381	10.283897	Point_23/Point_23
	65	Point ZM	Bare land	37.562051	10.268562	Point_23/Point_23
	66	Point ZM	Bare land	37.518913	10.215647	Point_23/Point_23
	67	Point ZM	Bare land	37.553531	10.16122	Point_23/Point_23
	68	Point ZM	Bare land	37.477562	10.104641	Point_23/Point_23
	69	Point ZM	Bare land	37.477692	10.043963	Point_23/Point_23
	70	Point ZM	Bare land	37.491351	10.016015	Point_23/Point_23
	71	Point ZM	Bare land	37.550108	10.013478	Point_23/Point_23
	72	Point ZM	Bare land	37.578578	10.057274	Point_23/Point_23
	73	Point ZM	Agricultural land	37.534396	10.225989	Point_23/Point_23
	74	Point ZM	Agricultural land	37.579803	10.21504	Point_23/Point_23
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	76	Point ZM	Agricultural land	37.75996	10.203031	Point_23/Point_23
	77	Point ZM	Agricultural land	37.731099	10.283345	Point_23/Point_23
	78	Point ZM	Agricultural land	37.70144	10.32993	Point_23/Point_23
	79	Point ZM	Agricultural land	37.764465	10.321523	Point_23/Point_23
	80	Point ZM	Agricultural land	37.796447	10.340245	Point_23/Point_23
	81	Point ZM	Agricultural land	37.742632	10.38079	Point_23/Point_23
	82	Point ZM	Agricultural land	37.74369	10.411074	Point_23/Point_23
	83	Point ZM	Agricultural land	37.789596	10.400827	Point_23/Point_23
	84	Point ZM	Agricultural land	37.830914	10.43708	Point_23/Point_23
	85	Point ZM	Agricultural land	37.774337	10.514188	Point_23/Point_23
	86	Point ZM	Agricultural land	37.803215	10.545095	Point_23/Point_23
	87	Point ZM	Agricultural land	37.870351	10.529165	Point_23/Point_23
	88	Point ZM	Agricultural land	37.829141	10.575907	Point_23/Point_23
	89	Point ZM	Agricultural land	37.863408	10.561693	Point_23/Point_23
	90	Point ZM	Agricultural land	37.614392	10.053988	Point_23/Point_23
	91	Point ZM	Agricultural land	37.597911	10.099914	Point_23/Point_23
	92	Point ZM	Agricultural land	37.666925	10.165708	Point_23/Point_23

91	Point ZM	Agricultural land	37.597911	10.099914	Point_23/Point_23	
92	Point ZM	Agricultural land	37.666925	10.165708	Point_23/Point_23	
93	Point ZM	Agricultural land	37.487036	10.106805	Point_23/Point_23	
94	Point ZM	Agricultural land	37.446494	10.112944	Point_23/Point_23	
95	Point ZM	Agricultural land	37.652644	10.2408	Point_23/Point_23	
96	Point ZM	Settlement	37.840807	10.604732	Point_23/Point_23	
97	Point ZM	Settlement	37.869193	10.573588	Point_23/Point_23	
98	Point ZM	Settlement	37.81254	10.572246	Point_23/Point_23	
99	Point ZM	Settlement	37.788091	10.529523	Point_23/Point_23	
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103	Point ZM	Settlement	37.792597	10.416375	Point_23/Point_23	
104	Point ZM	Settlement	37.723591	10.3375	Point_23/Point_23	
105	Point ZM	Settlement	37.778434	10.321288	Point_23/Point_23	
106	Point ZM	Settlement	37.680044	10.259551	Point_23/Point_23	
107	Point ZM	Settlement	37.780257	10.183178	Point_23/Point_23	
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109	Point ZM	Settlement	37.668171	10.148809	Point_23/Point_23	
110	Point ZM	Settlement	37.552874	10.164985	Point_23/Point_23	
111	Point ZM	Settlement	37.559515	10.263708	Point_23/Point_23	
112	Point ZM	Settlement	37.447823	10.107261	Point_23/Point_23	
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114	Point ZM	Settlement	37.458784	10.031906	Point_23/Point_23	
115	Point ZM	Settlement	37.458784	10.031906	Point_23/Point_23	
116	Point ZM	Settlement	37.594496	10.031856	Point_23/Point_23	
117	Point ZM	Settlement	37.604953	10.119159	Point_23/Point_23	
118	Point ZM	Settlement	37.62593	10.225061	Point_23/Point_23	
119	Point ZM	Settlement	37.716549	10.278458	Point_23/Point_23	
120	Point ZM	Settlement	37.739114	10.348334	Point_23/Point_23	
121	Point ZM	Settlement	37.749646	10.447901	Point_23/Point_23	

Appendix 9. Land use land cover changes of Chemoga watershed (1993 -2003)

	> LAND COVER CHANGE MATRIX [metre^2]						
	> NewClass						
V_Refere	-999	1	2	3	4	5	Total
-999	2151882000	0	0	0	0	0	2151882000
1	0	72643500	13858200	15966000	13829400	10857600	127154700
2	0	198249300	73972800	25891200	106902900	38723400	443739600
3	0	27717300	25929900	54904500	26764200	19353600	154669500
4	0	12612600	30890700	16091100	32577300	10993500	103165200
5	0	11351700	25823700	105371100	87444900	110559600	340551000
Total	2151882000	322574400	170475300	218223900	267518700	190487700	3321162000

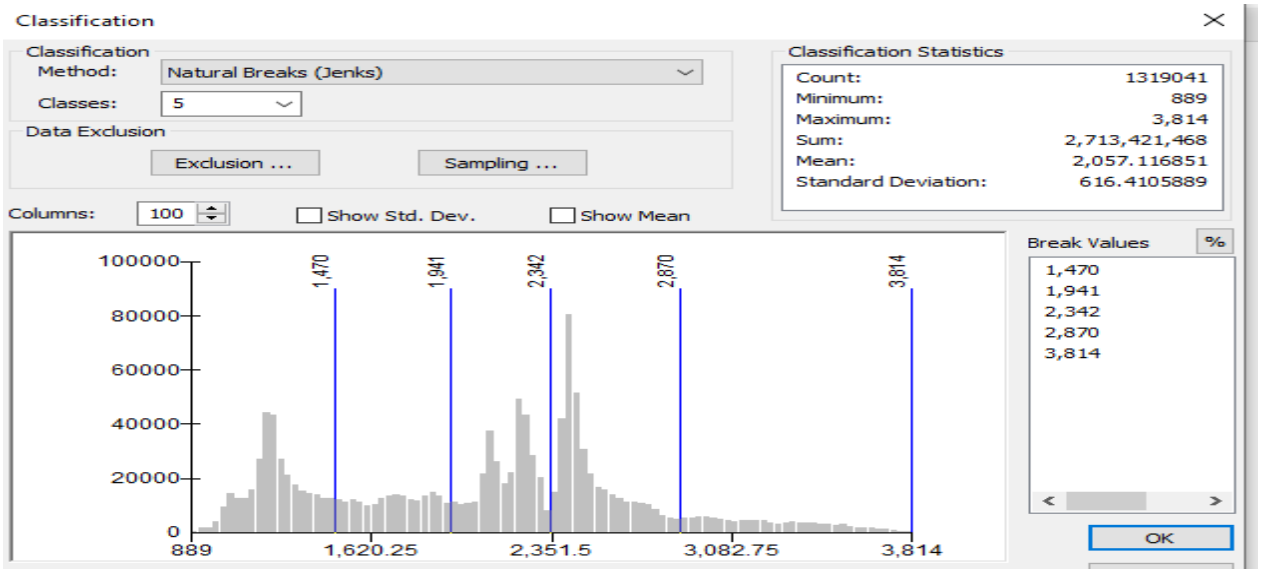
Appendix 10. Land use land cover changes of Chemoga watershed (2003 - 2013)

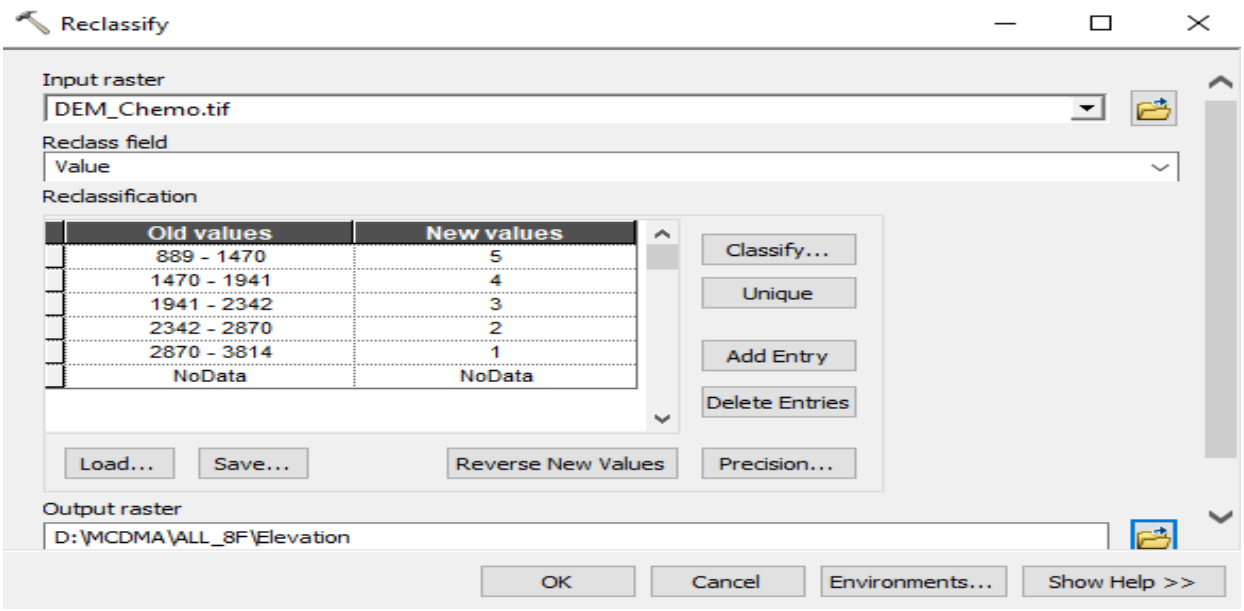
	> LAND COVER CHANGE MATRIX [metre^2]						
	> NewClass						
V_Referenc	-999	1	2	3	4	5	Total
-999	2151882000	0	0	0	0	0	2151882000
1	0	21903300	141119100	80298900	52492500	26760600	322574400
2	1800	7475400	22024800	97833600	26604000	16535700	170475300
3	1800	5400000	27152100	143597700	36828000	5244300	218223900
4	2700	8034300	95513400	28410300	72695700	62862300	267518700
5	2700	11217600	13708800	120874500	30938400	13745700	190487700
Total	2151891000	54030600	299518200	471015000	219558600	125148600	3321162000

Appendix 11. Land use land cover changes of Chemoga watershed (2013 - 2023)

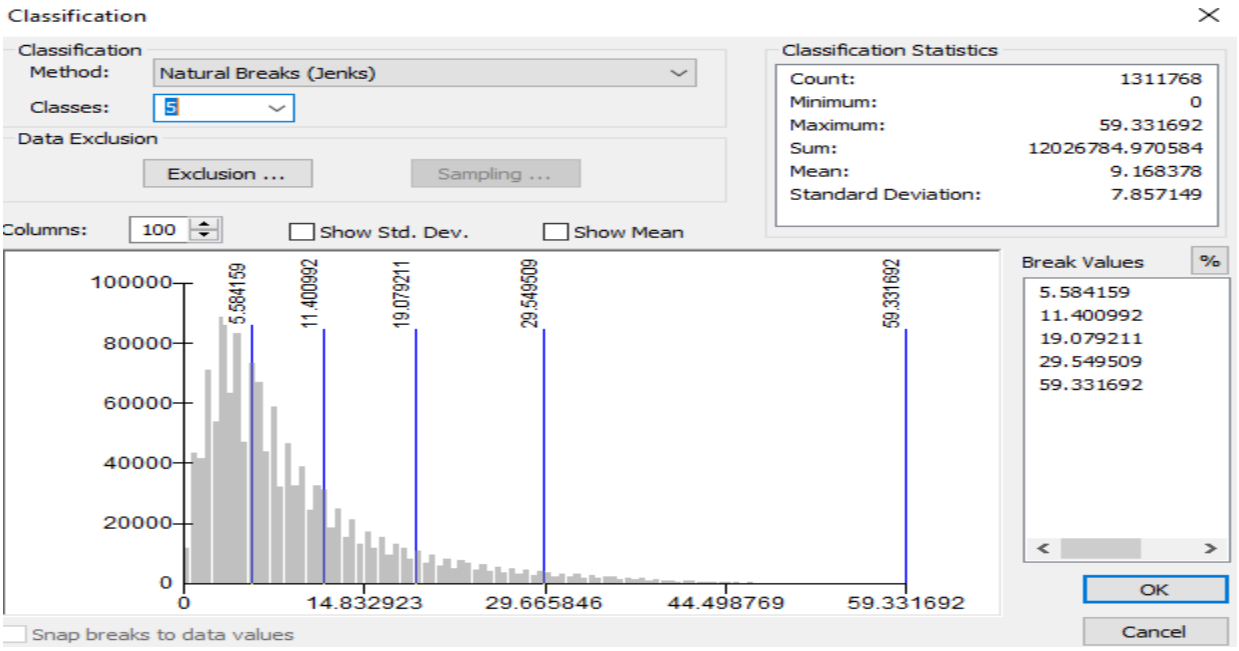
	> LAND COVER CHANGE MATRIX [metre^2]						
	> NewClass						
V_ReferenceClass	-999	1	2	3	4	5	Total
-999	2151882000	4500	0	900	0	3600	2151891000
1	3600	29802600	8497800	3185100	6314400	6227100	54030600
2	0	97572600	159591600	30009600	4347900	7996500	299518200
3	2700	233721000	121368600	90741600	4833000	20348100	471015000
4	2700	109874700	63677700	13697100	18823500	13482900	219558600
5	0	42309000	44610300	1726200	17195400	19307700	125148600
Total	2151891000	513284400	397746000	139360500	51514200	67365900	3321162000

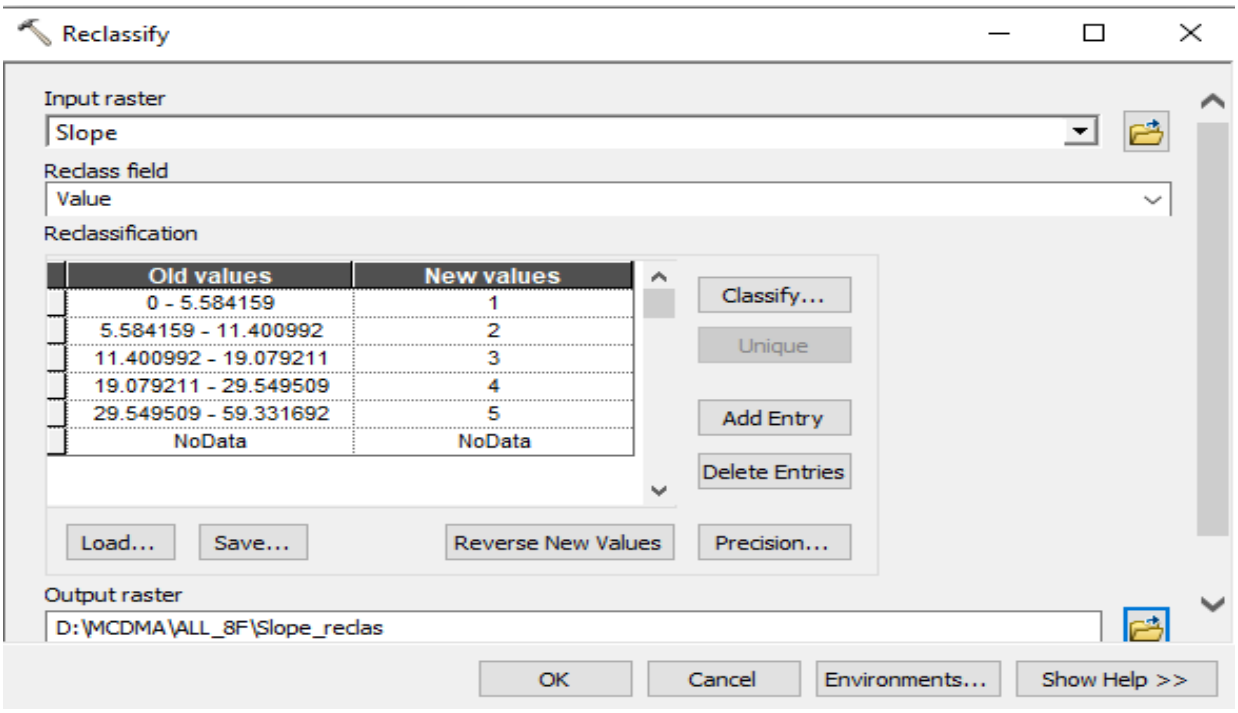
Appendix 12. Elevation



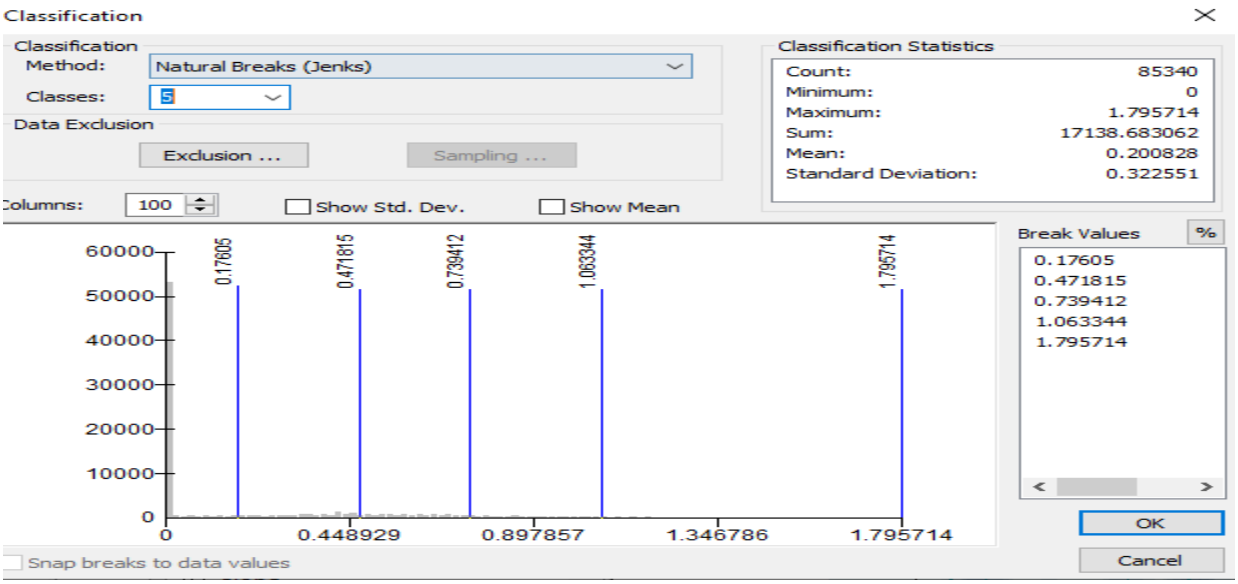


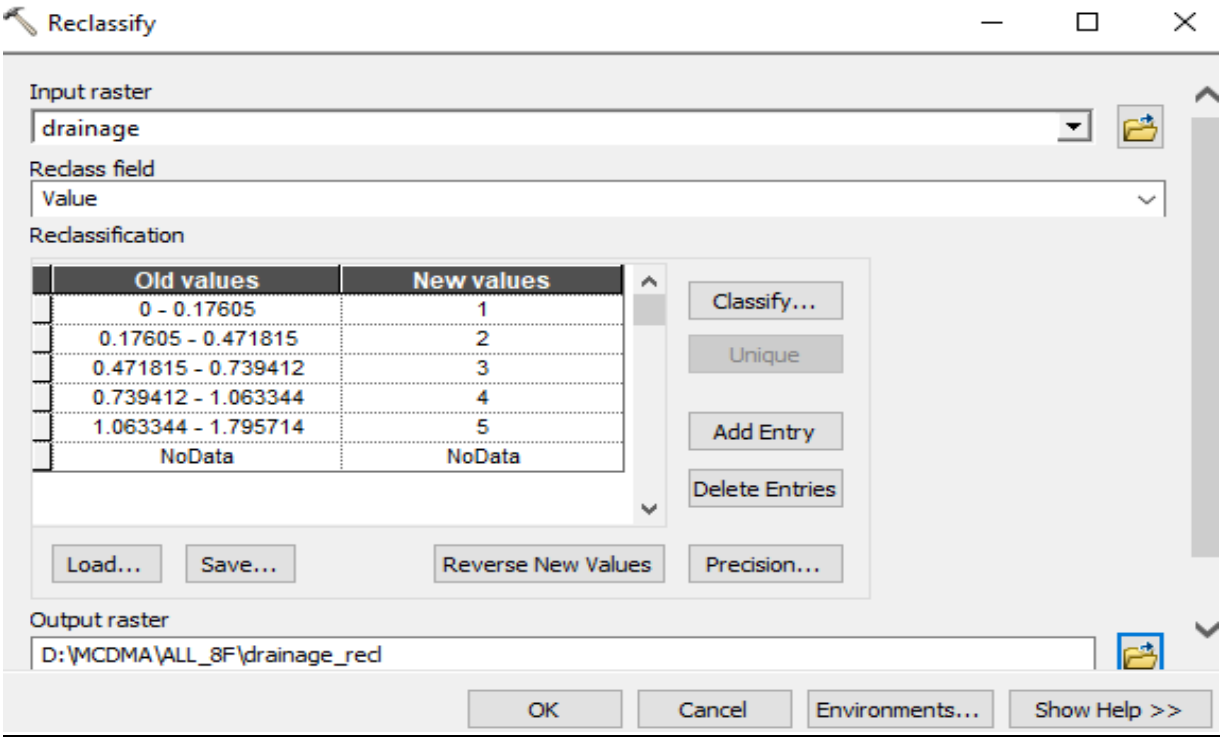
Appendix 13. Slope



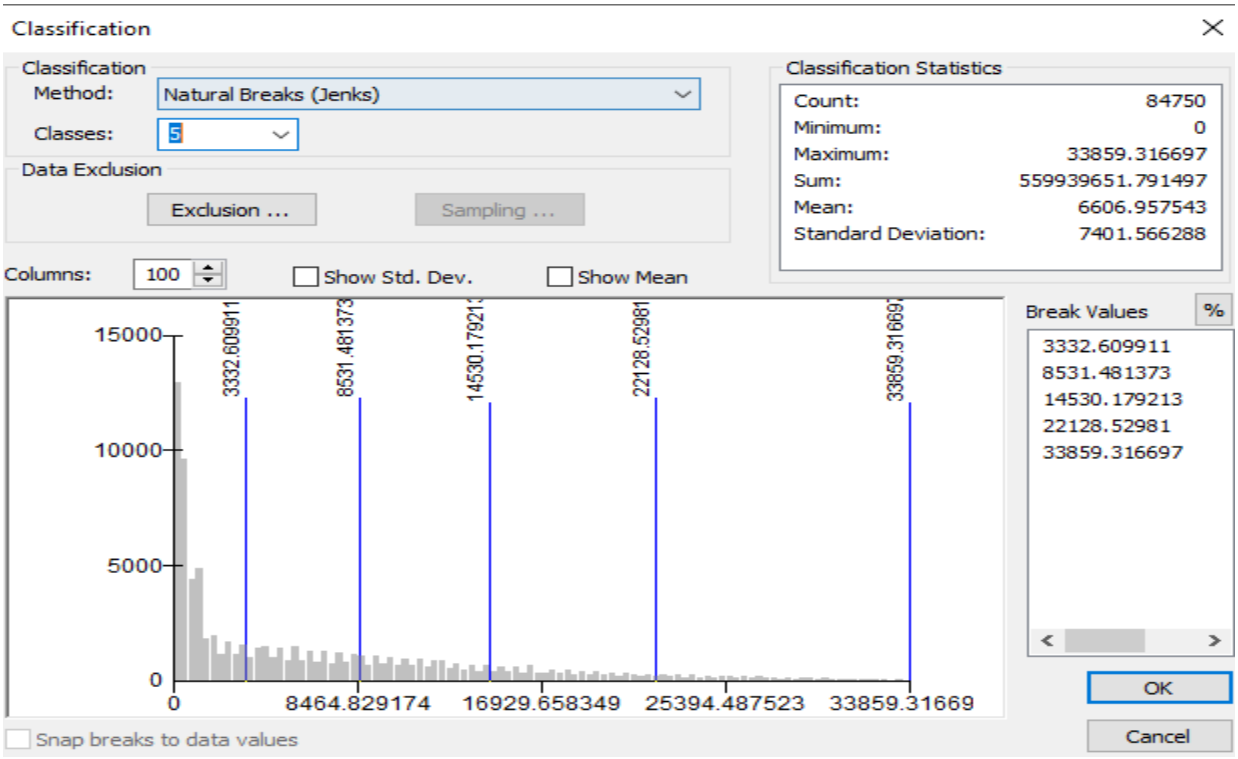


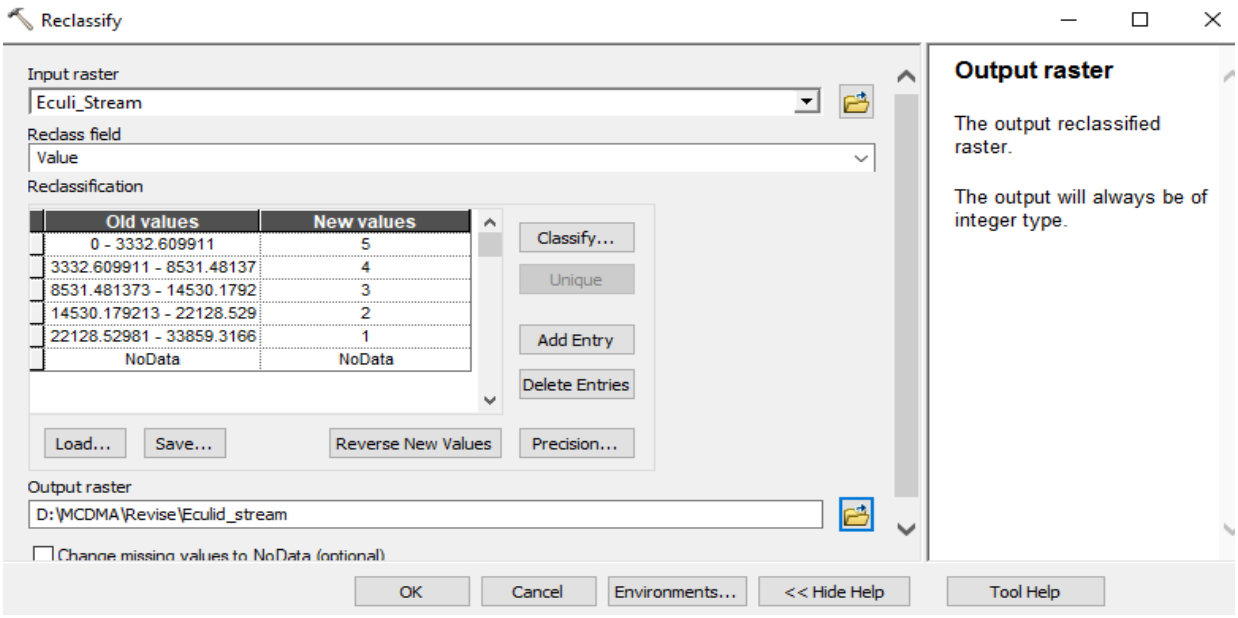
Appendix 14. Drainage density



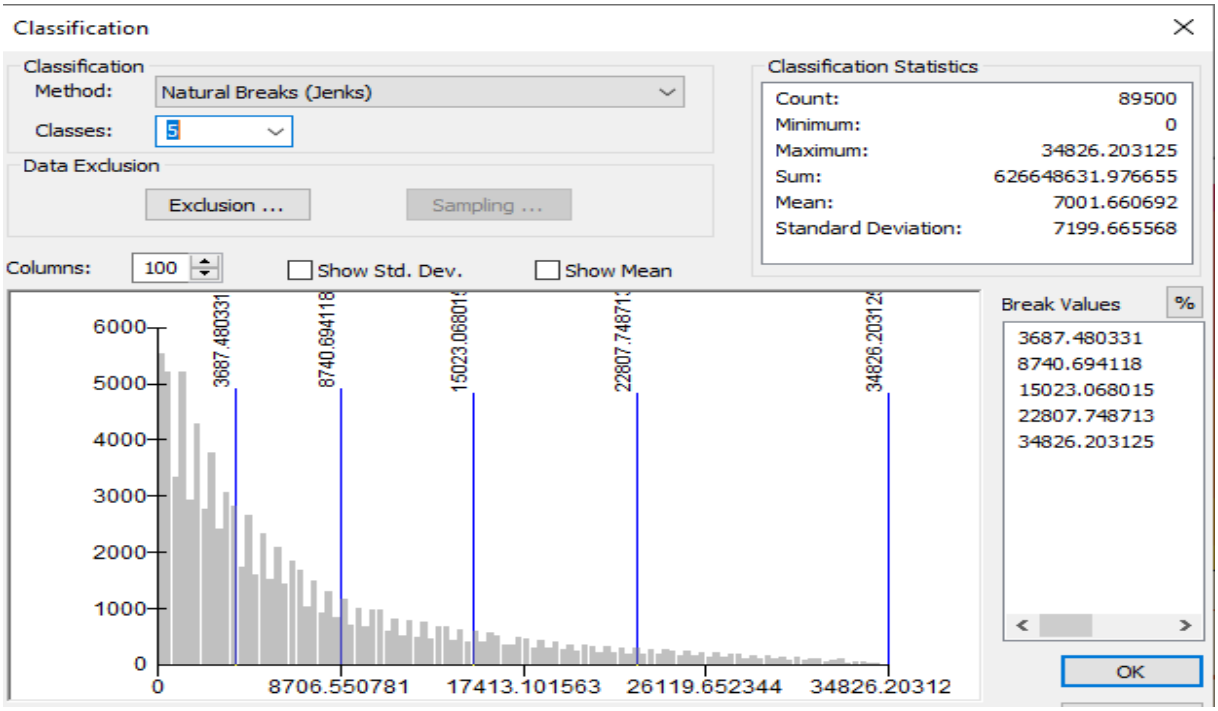


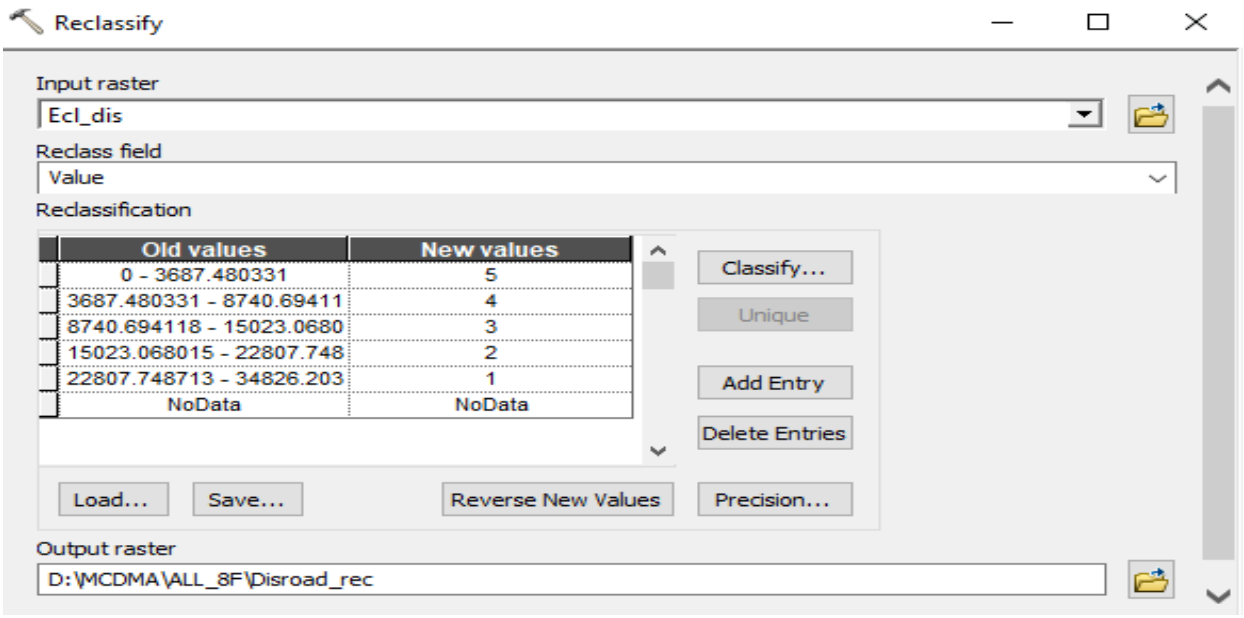
Appendix 15. Distance to river



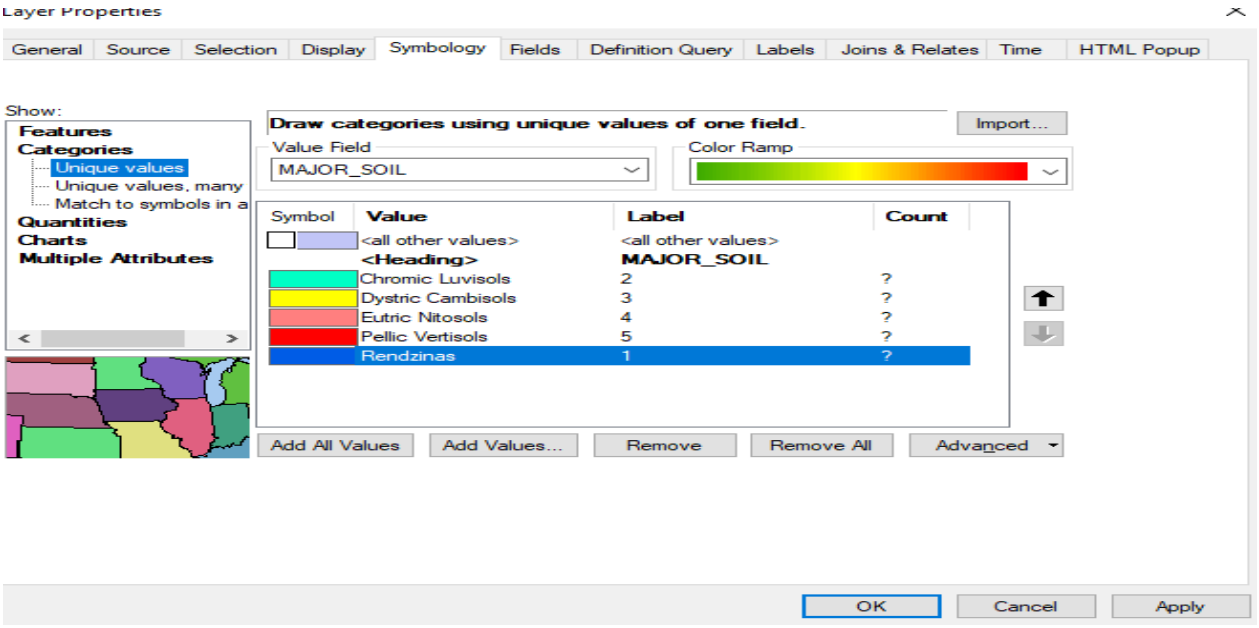


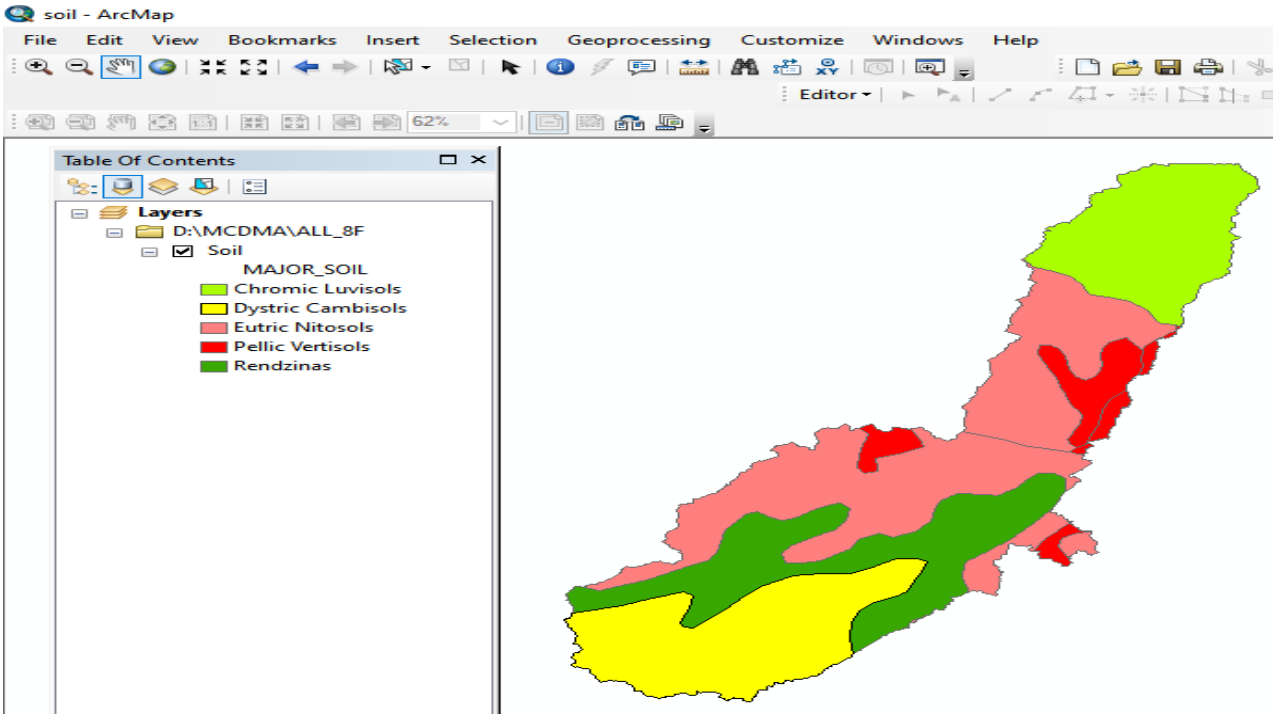
Appendix 16. Distance to road





Appendix 17. Soil




soil - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Editor
62%
Table Of Contents
Layers
D:\MCDMA\ALL_8F
Soil
MAJOR_SOIL
Chromic Luvisols
Dystric Cambisols
Eutric Nitosols
Pellic Vertisols
Rendzinas