Flood Risk Assessment Using Geographic Information System Techniques: In Guba Lafto District, North Wollo Zone, Amhara National Regional State, Ethiopia.

Dinku Ebabu
Jimma University https://orcid.org/0000-0002-1656-3604
Fikadu Fufa
Jimma University
Asnake Boyana
Arba Minch University
Getahun Sisay (getahunsisayteshager@gmail.com)
Debark University, Debark

Research

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Abstract

Background

In Ethiopia, flooding has long been recognized as one of the major environmental perils that often develop into a disaster affecting the lives and livelihoods of people for many years. Assessing flood causative factors and identifying flood risk prone areas are very crucial to minimize the harmful consequences of the hazard on the socio-economic conditions of the environment.

Result

The causative factors of flooding were developed and converted into raster formats to make them classification-ready. Finally, weighted overlay analysis is used to generate the flood risk areas. Based on key factors, the district was classified in to five-risk classes namely; very low, low, moderate, high and very high-risk Flooding zones. The major finding of the study prevails that, most areas of the district is at low, moderate and high-risk zones accounts 25.58, 61.41 and 12.81% respectively.

Conclusion

The flood prone area is mainly found in the eastern and southern parts of the study area based on their LULC type, soil characteristics and nearness to rivers. The study demonstrates, a significant area of the district is at a high risk for flooding and hence preliminary measures should be taken with the concerned bodies to reverse the resulting adverse impacts on environment.

1. Introduction

Flood is among the most devastating, widespread and frequent natural hazards of the world. It causes 31% of the total loose from all disasters; particularly river flood is one of the widest spreading and devastating natural disasters for many countries (Yahaya, 2008).

From 1990–2010, floods were responsible for the death of 200,000 people and making of 3 billion people homeless in the world (Smith, 2013). It is estimated that on average almost 200 million people in more than 90 countries are exposed to catastrophic flood events every year and it is expected to rise in future due to climate change and the steady demographic growth, as well as urbanization (UNESCO, 2008).

According to Danel (2007) in most cases flood in Ethiopia is linked with the heavy rainfall and its topographic features. The prolonged rainfall causes the river and small valley to force over flow from the upper parts of the region to damage the low laying areas which is along the river banks and it is very common in summer season of Ethiopia, where maximum rainfall is raining in most parts of the country (July and august.) Terrain characteristics of land and meteorological properties of the region are the main natural factors for causing flood disaster. With different land use and watercourse characteristics, intensive rainfall around the highland regions causes flooding and forced the river to flow in a wrong way to damage the riverbank and affect the low laying surfaces.

The country mainly experiences flash and river floods, Flash floods whose response time of the drainage basin is short) occur in lowland areas when excessive rains fall in adjacent highland areas, river flood on the other hand, in reverse to flash floods, mainly staying over days, or even month (NDRMC, 2016). Most parts of Ethiopia; particularly the northern part of the country characterized by up and down topographic features. Ended, as the higher parts of the district receive more rainfall, it immediately flows in to the lower parts of the area and results in devastating of low laying places. These the areas are exposed for flooding easily after the rain fall events, since it lacks concrete scientific basis to link land dynamics to floods (Kefyalew, 2003).

Different types of land use/cover change greatly influence the magnitude and intensity of flood. In addition to this, increase population has led to land dynamics which in turn leading to loss of natural vegetation and alteration of natural drainage system can affect the surface runoff and the infiltration capacities. Most studies, such as Daniel (2008), Tesfaalem (2009) and Abate (2011) for instance stated that, there is an incredible increase in cultivated and settlement at the expense of grazing land, shrub and bush land as well as natural forest. So, whenever the land use and land cover are changed, it may greatly affect the rate of flooding. Hence, quantifying of land use type is very critical for the adequate land use system to prevent the potential flood vulnerability of the community. In another way, lack of organized land use information leads the Guba Lafto District to worsen and tends to accelerate the rate of flood occurrence, since there is no any information about zoning of LULC for better management practice, while it is possible to identify and map the available LULC using GIS techniques.

The extent, magnitude and cause of potential flood risk for the study areas not well understood in terms of time and space across the region. So far, few researchers were conducted related flood problems in different parts of Ethiopia, (Woubet, 2011); (Kebede, 2012); (Belay, 2016), but their focuses were related to the impacts of flood and water resource. Following to this, especially the actual causes of flooding and map of flood-inundated areas not well understood. So, this research dedicated to fill these gaps, because, “less uncertain about flood led to better decision supporting system”. Moreover, identification and evaluation of flood causative factors can allow for better mitigation and prevention mechanisms for the flood risk authorities to give fast and cost-effective measurements. Now days, GIS and remote sensing technology plays a key role in flood risk assessment and or mapping. Hence, the aim of this research was to identify flood prone area based on certain factors such as land use, slope, rainfall and drainage density and producing flood prone map of Guba Lafto district using GIS techniques with MCE methods.

2. Materials And Methods

2.1 Description of the study area

Guba Lafto District is located in South Wollo Zone Amhara region, Ethiopia. Astronomically, the area lies between 39^{0}6'9" and 39^{0}45'58" East of longitude and 11^{0}34'54"and 11^{0}58'59" North of latitude.

The topography of the Guba Lafto district dominated with mountains of chain, hills and many small valleys (up and down). altitude ranges from 1379 to 3809 m above sea level (m.a.s.l). Gubalafto Woreda has four Agro-ecological zones, namely, lowland 1379–1500 m.a.s.l, (17%), mid-altitude 1500-2300m.a.s. l (46%), Highland 2300-3200m.a.s. l, (37%) and Wurch > 3200 m.a.s.l. (2%). Mostly peoples in this District segregated around the high land areas (Alemu, 2011). The annual mean minimum and maximum temperatures for Guba Lafto werda are ranging from 7.5 to 22.40C. According to the study of Belay (2016), the major soil types in Guba lafto are Eutric and Leptosols, while Eutric Cambisols, Lithic Leptosols, and Vertic Cambisols also observed.

2.2. Research Design

The study followed mixed approaches of qualitative and quantitative methods of data analysis. Qualitative approach is followed for analyzing and describing the socio-economic data which was gathered from selective experts from the minister of agriculture and water resource management and local office particularly for participating in ranking of decision criteria. Determining of weight of the factor, standardization and classified the criteria are included under quantitative analysis.

2.3. Materials and Methods

2.3.1. Software Use

ArcGIS tool of image classification was utilized for satellite image classification. ArcGIS software was used to generate the factor maps integrating with MCE methods. Flow accumulation, flow direction, and stream networks were computed using Arc Hydro tools in GIS environment. Garmin GPS 60 was used to collect ground truth points to validate the LULC classification result.

2.3.2. Source of Data

This study was used both primary and secondary data sources. The primary source of data includes GPS, filed survey and key informant interview. While secondary data sources include; both published scientific researches, internet websites to obtain remotely sensed satellite image, ministry of agriculture and national meteorological agency of Ethiopia to collect soil map, and rain fall data respectively.

3. Methods Of Data Analysis

Supervised image classification using maximum likelihood classifier algorithm was used to classify the land use/cover change. The accuracy assessment was conducted to check the correctness of the classified image with reference information using error matrix.

To calculate the total accuracy of LULC, Kappa Coefficient. Which is the measure of agreement is calculated.

$$K = \frac{\textbf{observed Acuracey} - \textbf{Change agrement}}{\textbf{change agrement}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. (1)}$$

K is the difference between actual agreement and the agreement expected by chance. Producer accuracy, user accuracy and Kappa coefficient are calculated to use different accuracy assessment and to make the result valid since different criteria is important to evaluate the image classification and provide error bounds on accuracy.

3.1 Identification and Evaluation of Criteria

In multi-criteria evaluation system, the selection of criteria is very crucial steps (Malczewski, 1999). Therefore, the basic criteria used in this study is selected based on the literature review and their relevance in the study area. As to Eisenbies et al. (2007), Flooding is influenced by different factors such as, the duration, intensity and spatial extent of rainfall, soil depth and structure, and catchment size, the full range of land uses occurring in the catchment including agriculture and urbanization, enhanced drainage as a result of urbanization, and roads. Hence the followings are the main criteria for flood causative factors. So that there are six factors which is selected for this study namely; Slope, drainage basin, Soil type, elevation, rainfall, and land cover map. Those six criteria were chosen as the most important factors for evaluating the probability of an area vulnerable for flood risks (Tanavud et al., 2001).

3.2. Land Use Land Cover analysis

The land use and land cover of the study area is the primary concern in flood risk mapping. It is not only showing the current land use types alone, but also the importance of its use in relation to soil stability and infiltration. Land cover which is covered by grassland or the cover of other forests, is better than bare lands for water to store to reduce runoff. Hence the availability of vegetation thickness can slow down the runoff. On the other hand, land use like bare lands, buildings and roads can accelerate soil erosion and intensified flooding since their infiltration capacity is very low. As a result of this, the type of LULC plays a key role in determining of flood occurrence for particular topographic features in flood risk mapping. Based on the run off resistance of each LULC discussing with the selective key informants and published literatures related to flood criteria, the available LULC type were classified in to five classes. So that, bare lands were considered as very high risky, while crop, grass, shrub and forest lands were respectively given high, moderate low and very low cause for flood risk.

3.3. Soil Type

Different soil types have different impact for flood occurrence and resistance. Based on the nature of soil types for water holding capacity, the existing five soils were further categorized according to their risk class for flooding (FOA, 2007). Similar studies for instance, Ryutaro (2014) classified soil type in to different ways and different numbers since the type of soil is unique across regions. As a result of this, by considering the physical characteristics of the available soil to their water holding capacity, the soil types were classified in to five risk levels. Leptosols is assigned as very high risky (1) to flooding while xerosols, regosols, phemosols and cambisols, are respectively weighted as high (2), moderate (3), low (4) and very low (5) risky for flood risk zone.

3.4. Slope

The slope of the study area was derived from the ASTER DEM using the ArcGIS spatial analyst tool and converted in to raster layers before conducting the reclassification process for flood risk zones. The slope of an area has a substantial impact on runoff by affecting both its direction and amount of surface runoff or subsurface drainage reaching in to an area including its duration of time to reach drainage. The nature of slope and its relation with soil and other earth materials like drainage and lithological property can greatly affect surface runoff. For example, a smooth/flat surface that permit the water to flow faster and causes flooding, on the other hand, a terrain with roughness and steep slope can slow down its speed. According to Ozcan (2010), flatter surface slopes are highly vulnerable to flood occurrences compared to steppe slopes. In fact, water is always flow from the high to low land and gathers sediment and other particle to the low laying areas. Area with higher gradient slope cannot able to accumulate water and tends to cause flooding in case of river type of flooding. But in this study, the main concern is mainly with flash flood types.

3.5 Elevation

Different elevation has different capacity to resist a flood. As the elevation value of a topography increases, its probability to be exposed for flood related hazards will be low and vice versa. Hence, low laying areas will be considered as victim from the hit of such hazards and sedimentation activities.

Based on this the elevation value of the study area classified in to five suitability classes for causing of flooding.

3.6. Drainage density

Drainage density map was derived from the ASTER 30m *30m resolution DEM of the study area. Using the spatial analysis tool, flow direction and accumulation were calculated and assign the length of streams using raster calculator to consider the number of streams to be used. Next to this, the drainage density was generated using the following formulas.

$$\boldsymbol{D} = \frac{\mathbf{D}}{\mathbf{A}} \text{ ....Eq. (2)}$$

Where **D** is drainage density of watershed of an area; **L** is the total length of a drainage channel in a watershed of an area (km); and **A** is the total area of the watershed in the area (km^2). According to Ryutaro (2014), aduqate drainage denisy areas has more probability to be affected by floods than those low drainage density.

3.7. Rainfall

The amount of rainfall, intensity, duration and spatial distribution influences the flood events. Flash floods due to relatively small cells of conventional activity have received much attention. This is because mostly rainfall cannot immediately infiltrate as ground water, the extreme rainfall raises the amount of discharge from rivers and causes overflowing.

Like any other flood causative factors, rainfall was considered as one of the major causes of flooding for this study. Therefore, flood can happen when there is a heavy rainfall and when the watercourse of an area is unable to manage it. Hence runoff is as a result of excess rain fall and its poor watershed management. When rain is raining over the area, then the level of water rises above its river banks and tends to overflow. This type of flooding is mainly flash floods which affect flow from the highland towards the low land and it will then damage the low-level areas.

For this study, mean average monthly rainfall for seven years (2001–2007) was used to create a continuous surface rainfall values using Inverse Distance Weighting (IDW) interpolation technique. Therefore, the product of raster values was further classified in to five risk classes based on the amount of rainfall they receive.

3.9. Slope, flow accumulation, flow direction and drainage basin

“The topography of the land surface is one of the most fundamental geophysical measurements of the Earth, and it is a dominant controlling factor in virtually all physical processes that occur on the land surface”, (Evangeliai, 2013). Hence, topographic related information like slope, flow accumulation and flow direction as well as drainage basin are the valuable data for recent study. These morphometric characteristics were computed using ASTER global DEM as input. Using the cut and fill DEM as an input, it was generated the flow direction, and also flow accumulation was produced using the already derived flow direction. Beside this, flow accumulation, was used as an input to calculate stream orders, using map algebra raster calculator. Finally, the drainage networks were calculating in the line density tool using stream feature as an input. Slope and elevation on the other hand, was generated using ArcGIS 10.3 software with Arc tool of surface analysis. All flood causative factors were classified in to five sub classes according to their risk classes based on the available parameters. Hence, to generate the final flood factor map, reclassification was conducted by taking their flood resistant potential in to account. Following to this, areas with low resistant of flooding was assign as high risky and vice versa.

3.10 Multi Criteria Evaluation (MCE)

MCE is one of the appropriate mechanisms to delineate flood prone areas with GIS methods. Multi criteria analysis was applied and integrate with the spatial data in order to describe the causative factors of a phenomenon under concern (Fadlalla, 2015). There are different approaches of MCE which is integrating with GIS environment. Amongst them, the weighted overlay, and Weighted Linear Combination (WLC) approaches are among the important methods which were applied for this study. In order to run MCE, it was developed the causative factors like land use, slope, rain fall, elevation, drainage density and soil type map by using pair wise comparison method, and analyzing of those causative factors of flood effectively (Yahaya, 2008).

3.11 Weighted Overlay Analysis

Weighting of decision factors was determined based on the importance of each variable in determining the flood causative factors which is determined mainly based on the expert knowledge and opinions. Hence according to Malczweski, (1999), there are different factors that might affect flood such as land use, soil type, elevation, rain fall, drainage land use, soil type, rain fall, drainage system, elevation, and so. For study, six factors were assessed namely, land use, soil type, rain fall, drainage basin and slope. Those six factors were overlaid numerically using weighted overlay analysis. Each of the six layers of map was also reclassified. The following equation is used to overlay those factors (Eastman, 2001).

$S = \Sigma wixi$ ………………………………………Eq. (5)

S is suitability index for each pixel in the map; **wi** is the weight of **ith** factor map, and **Xi** is criteria score of class of factor **i**.

3.12 Weighted Linear Combination Methods

In WLC methods, pair wise comparison method and ranking method was applied for this study. Ranking technique involves ordering of decision factors in their relative order of importance, Wale et al. (2013), where every criterion under consideration was ranked in the order of the decision maker's preference. Hence, the factors were weighted based on their capacity of flood occurrence. Among the type of ranking methods, Inverse Ranking Method was applied to these factor classes (Saaty, 1980). As to Satty (1980) in case of inverse ranking (the least important = 1 next least important = 2 etc.) or the last X in this case (5) is the most important, 4 is second important etc.

Based on this, using weighted overlay analysis methods, the risk areas were generated by using numerically overlaying techniques of soil, land use, drainage density, and slope as well as rainfall layers, (Fadlalla, 2015). Then each factor was divided into classes according to their importance in causing flood based on the expertise opinions and the availabilities of data. Pairwise comparison matrix method is useful for the comparison of the criteria and enables the comparison of two criteria at a time. Moreover, this method can enables changing the subjective perception in to linear weights (Kevin and Musungu, 2012).During weight determination by the experts for the criteria, their opinion and judgments may not agree perfectly. Therefore, to compensate those variations Consistency ratio was intended to apply to measure the level of consistency achieved in the ratings. In Consistency ratio, when a CR value is equal to 0.1, it implies that the matrix is an acceptable, when it exceeds to 1, the matrix is needed to revise again. Revising the matrix entails, finding inconsistent judgments regarding to the importance of criteria.

4 Results And Discussions

4.1. LULC of the Study Area

The Land sat ETM$^+$ of 2016 satellite image was used to classify the LULC map of the study area by using the supervised image classification technique. Hence, the LULC of the study site was classified in to five main classes namely, forest land, cropland land grass, shrub land, and bare land as it is shown in figure (3).

Based on the classification result, forest area covers about 5.8% of the total land mass and mostly forests are found in the highland parts of the study area. Almost greater than half of the total land mass of the study area is covered by crop land. It consists of 68% of the total area. Grass land; on the other hand, share 7% of the whole area, which is the third dominant LULC type and which is observed in the central and eastern parts of the study area. As far as Shrub land concerns, this type of land use/cover is mostly found in the eastern and central low land part of the study area, and the second dominant land use type which consists of 18% of the total areal coverage. Lastly bare land is found in the south east regions of the study area and which accounts a very small proportion shares only 1.21% of the total land masses.

4.1.2 Accuracy Assessment

Based on Ismail and Jusoff (2008) the agreement criteria for Kappa statistics (K) are defined as, poor when $K < 0.4$, good when $0.4 < K < 0.7$ and excellent when $K > 0.75$. Accordingly, the LULC classification of the study area was 0.86, indicating that the agreement criteria were excellent. Its overall accuracy is 89 % with its kappa coefficient of value of 0.86. Hence a value of 0.86 kappa coefficient can highly support the strong arguments of the land use/cover classification system. In addition to Kappa coefficient producer's accuracy and user accuracy was also calculated. the user and producer accuracy are minimal in the case of crop land compared to the rest of the other LULC types; this is because of the fact that, the crop land is mostly similar with the grass land while the LULC identifications process was running.

Table 1
Accuracy assessment of the study area LULC classification matrix

LULC	Forest	Crop	Grass	Shrub	Bare	producer accuracy	user accuracy	Total
Forest	**15**	0	0	0	0	88.2	100	15
crop land	1	**17**	2	2	0	85	77.23	184.23
Grass	1	1	**17**	0	0	89.48	89.5	197.98
Shrub	0	2	0	**14**	0	87.5	87.5	191
bare land	0	0	0	0	**14**	100	100	214
Total	7	20	19	16	14			86

4.1.3 Flood Risk evaluation of LU/LC Type

According to Morita (2014), the LULC of the study area is the primary concern in flood risk mapping. Land cover which is covered by grassland or the cover of other forests, is better than bare lands for water store to reduce runoff. Hence the availability of vegetation thickness can slow down the runoff. On the other hand, land uses like bare lands, buildings and roads can accelerate soil erosion and intensified flooding since their infiltration capacity is very low. As a result of this, the type of LU/LC plays a key role in determining of flood occurrence for particular topographic features.

Since there is no uniform classification system about LU/LC reclassification for flood cause due to variation in LULC from place to place and even the variation of flood frequency and intensity, the local experts were selected and discussed with the reclassifications of LULC for causing of flooding.

Table 2
Expert determinations of LULC for flood cause

LULC types	Risk level				
	Very high risk	**High risk**	**Moderate**	**Low risk**	**Very low risk**
Forest					X
Bare land	X				
Crop land		X			
Grass land			X		
Shrub land				X	

The experts of Guba Lafto District of Agricultural Office were determining the LULC cause for flooding by considering the characteristics of LULC for runoff resistance. Therefore, by considering their impact for flooding with discussing the selected key informants of Guba Lafto District experts and the nature of each land use to its water holding capacity, it was further reclassified in to five risk classes. Based on this, bare land, cropland, grass, shrub and forest lands are respectively assigned as very high (1), high (2), moderate (3), low (4) and very low (5) for causing of floods. Therefore, the following map shows the land use/cover factor map of the study area.

Figure 4.2 implies that a large proportion of an area is covered by crop lands 68944.2 % (68.3 ha) which is assigned as high flood risk classes, therefore, the probability of an area to be affected by flood risk is higher when flood risk is evaluated by using the LULC parameter as it is supported by the experts of agriculture of Guba Lafto District. Beside this, only 524.2 ha (1 %) is covered by bare land which is already assigned as the most cause for flooding as the capacity of bare land to resist flood is very poor. While, 5855.7 (5.9%) of the total area is covered by forest lands which is very good for flood resistant. Grass land and shrub land is moderately affected floods which consists of the parts of the total land shares (7210.7 ha or 7.4 % and 18338.2 ha or 18.2 %) respectively.

4.2 Soil Types and their Relation to Flooding

There are five soil types identified in the study area, namely cambisols, regosols, pherosols, leptosols and xerosols.

Cambisols have good structure and mainly the degradation activities are not highly affected it since their high resistance for such types of processes. It contains at least some weatherable minerals in the silt and sand fractions. This soil type is mostly found in areas where there is adequate amount of rainfall like in temperate and boreal regions. Cambisols are medium textured and have good structural stability, high porosity, and good water holding capacity and good internal drainage.

FAO (2007) focused up on the concept of Regosols to mean well drained, medium textured, deep mineral soils derived from unconsolidated materials and separated them from shallow soils (Lithosols, Leptosols, etc.) and from those with sandy or coarser textures (Arenosols) and are mainly recent deposit earth materials.

Leptosols are soils, which are limited in depth by continuous hard rock within 30 cm of the soil surface, or contain or overlie within the same depth material with very high calcium carbonate content, or are very grave. Leptosols represent the initial phases of soil formation and are the products of severe erosion. The concept of Leptosols is to comprise all shallow, or very stony, soils overlying rock, partially altered rock or strongly calcareous material, or soils with a limited amount of fine earth material.

Most Leptosols are under natural vegetation, which is generally richer on calcareous ones than on the acid types. The main physical constraint of Leptosols is their low water holding capacity, which makes them very susceptible to drought stress. Leptosols have severe physical limitations for arable cropping, but have a certain potential for trees and for extensive grazing. The better types are the ones developed on limestone under a humid climate. Tree roots find anchorage by entering fissures. In mountain regions, soil erosion is a major problem with Leptosols under arable crops.

Pherosols have a good structure and are generally resistant to erosion. The impact of yiled products is greatly affected if those type of soils are eroded, (FAO, 2007). The favorable physical and chemical properties, especially the stable structure, high porosity and high available water capacity, high levels of organic matter, relative richness in nutrients and medium to high base saturation make these soils excellent farm land.

Xerosols on the other hand is the deserts soils, with low levels of organic matter and mainly Subject to wind erosion and concentration of soluble salts.

4.2.1 Soil flood Risk Assessment for Flooding

Soil type data were again reclassified in to five flood risk classes by using arc tool box in arc GIS 10.3 by considering its water holding capacity for flooding as each type of soils have different impact for flooding.

Based on the nature of soil types for water holding capacity, the existing five soils were further categorized according to their risk class for flooding, (FOA, 2007). Similar studies for instance, Ryutaro (2014) classified soil type in to five risk levels namely very high, high, moderate, low and very low, based on the study area soil characteristics, since the type of soil is unique across regions. As a result of this, by considering the physical characteristics of the available soil to their water holding capacity, the soil types were classified in to five risk levels. Leptosols is assigned as very high risky (1) to flooding while xerosols, regosols, phemosols and Cambisols, are weighted as high (2), moderate (3), low (4) and very low (5) risky for flood risk zone respectively.

Based on the evaluation of soil parameter for flood risk for the study area, almost 31 % of the total land masses are at risk, this is because of the poor water holding characteristics of leptosols and regosols, which consists of 31 % together. As a result of this, leptosols and regosols are assigned as the main cause of flood for the study area since the soil property of water infiltration ability is very low as it is briefly discussed in section three. The following figure shows the flood risk map of soil for the study area.

4.3 Slope and its Risk Assessment for Flooding

The slope of an area plays a substantial role in controlling of water runoff. The nature of slope greatly affects or influences the runoff direction and its amount to reach in a particular drainage. Moreover, slope also influences the infiltration capacity of topographic features. The nature of slope and its relation with soil and other earth materials like drainage and lithological property can greatly affect surface runoff. For example, a smooth/flat surface that permit the water to flow faster and causes flooding, on the other hand, a terrain with roughness and steep slope can slow down its speed. In general, in the case of flood risk impact, Steeper slopes have more probability to damage by surface runoff, while flat terrains are susceptible to water logging.

According to (Ozcan 2010), flatter surface slopes are highly vulnerable to flood occurrences compared to steppe slopes. This is because of water from the river always gathers in an area where the slope gradient is usually low as water flow from high elevation to the lower. Area with higher gradient slope cannot able to accumulate water and tends to cause flooding in case of river type of flooding. But in this study, the main concern is mainly with flash flood types and the lower slope is the most vulnerable and vice versa. Hence, the concern is mainly for flash flood, so that the classification and weighted of soil for flood causing constraints is given by considering of it.

The slope with lower value is flatter and the highest value is the steeper feature of a terrain. Hence based on the susceptibility to flooding; slope have been classified into five classes. Therefore, the lowest slope area is very highly affected by flood and then ranked to class 1, which is less than 10 %. Following the very high classes, there is class high (20%) ranked 2, moderate (up to 30%) ranked 3, low (40%) ranked 4 and, and class very low (> 40%) ranked as 5,

As to most literatures, slope can be classified in to different ways according to the criteria and the nature of the study area. Therefore, based on the nature of the study area, this study was classifying the slope factor map of flood in to eight classes, and it again reclassified in to five suitability classes namely, very risky to flooding up to very low risky for flooding for gentle slope to steppe slope respectively in order to identifying the areas of flood risk.

The study result reveals that almost 58 % of the total land mass is at a high risk of flooding, while the 20 % is moderately risky and the remaining 19 % is at low risk of flooding. This means that the study area is the most risk for flooding when slope is the evaluated with the slope criteria. The central and eastern parts of the study area are generally at flood risk levels in the case of slope evaluation parameters, since the area is flatter and characterized by gentle slope.

4.4 Elevation assessment for Flood Risk

Different elevation has different capacity to resist a flood; for instance, When the elevation value of a topography is increase, then its probability to exposed for flood related risk will be low compared to the elevated areas and vice versa. This is because of the fact that runoff is began from the upper part of a surface to the lower part. As a result of this, low laying areas will be victimized from the hit of such hazards and sedimentation of different particles which comes from the upper areas

According to (Morita, 2014), the low laying areas are the most flood hit and the reverse is true for the elevated areas.

The study result indicated that 16090.28 (ha) or 15.96 (%) of the study area is found at a very high-risk zones while 24011.4 (ha) or 23.81 (%) of the study area is at high risk. The remain 19286.52 (ha) or 19.12 (%), 15032.28 (ha) or 14.91 (%) and 26452.32 (ha) or 26.22 (%) of the total land masses are moderately risk, low risk and very low risky respectively using elevation parameters as a criterion. Therefore, flood risk is relatively higher in elevation parameters like slope and LULC as it is described above.

4.5. Assessment of Drainage Density for Flooding

According to Strahler (1964), the higher the density, the higher the area is susceptible to erosion, which is resulting in sedimentation the low laying areas.

Based on this, an area with adequate drainage network has a drainage density value of ≥ 5 whereas the moderate drainage areas have a value of 5 – 1 and the poorest one has < 1. Therefore, in this study, streams of up to 4th order were considered in evaluating the drainage density of the study area. As a result of this, the higher weights were given for higher density areas drainage and lower weights were given to areas with poor drainage areas. The drainage density layer was further reclassified in five sub-groups using the standard classification Schemes (1–5). Areas with very low drainage density are ranked as 5 and those with very high drainage density were ranked with value of 1, and high risk, moderate and low risk areas were assigned as 2, 3 and 4 respectively.

Based on the table 4.6, 4472.91 ha (4.45 %) is characterized as the very high risk where 16632.81 ha (16.52 %) which assigned as very high risk. The reaming 23208.75 ha (23.05 %), 23208.75 ha (23.05 %) and 26788.68 ha (26.60 %) are parts of moderate, low and very low risk areas.

From this, the total land which is under risky zones is almost 20 % of the total areas, which implies that a study area flood risk hazards exposures is relatively lower compared with the rest of the other factor maps as the drainage density factor shows.

4.6 Rainfall

A mean average monthly rainfall for seven years (2001–2007) was considered and interpolated using Inverse Distance Weighting (IDW) to create a continuous raster rainfall. The reclassified rainfall was given a value 5 for least rainfall to 1 for highest rainfall as it is shown in Fig. 4.6 below.

4.6.1 Evaluation of Rainfall for Flooding

According to Woubet (2011), the classification of rainfall for flooding is determined by based on the amount of rainfall receiving of an area; as a result of this, the higher the rainfall an area possess, then the higher the probability of an area to be exposed for flooding. Ended, by considering the rainfall of the study area, Guba Lafto District was classified in to five flood risk classes. In this case the higher rainfall receives areas were assigning as high flood risk zones and the low rainfall receive areas were assigned as low flood risk zones.

As the Fig. 4.6 implies 3620.07 ha (3.58 %), amount of the study area is within a very low risk in terms of rainfall factor is used as a means of causing for flood occurrence. Whereas 13198.41 ha (13.08 %) of the study area ranges to high risk, and 29726.64 ha (29.47 %) is moderately risked for flood. The remaining 30276.27 ha (30.02 %) and 24050.61 ha (23.85 %) are low and very low risk zones respectively for flood hazard. Therefore, in this parameter, the study area is generally having a chance of affected by flooding is up to 19 %, and 30 % of moderately affected by flood.

4.7 Comparisons of each Criterion

Each of the six criteria has different impacts for flood occurrence as it is already notified by many literatures such as Morita (2014), Ryutaro (2014) and so on. Therefore, assessing the potential flood risk areas using either of one or two parameters may not be accurately represents the real situations. Table 4.3 illustrates the flood occurrence potentials of each of the six criteria mentioned above.

Table 3
comparison of the criteria risk level for flooding

Criteria	Risk levels and percent of risk classes				
	Very high risk	**High risk**	**Moderate**	**low risk**	**Very low risk**
LULC	1.21	68.32	7.42	18.23	5.91
Soil	28.71	3.70	17.24	49.58	0.77
Slope	30.25	28.70	20.71	13.76	6.63
Drainage	4.45	16.52	23.05	29.38	26.60
Elevation	15.96	23.81	19.91	14.91	26.22
Rainfall	3.58	13.08	29.47	30.02	23.85

From table 4.3, we understood that Guba Lafto district has very high probability to be affected by flood risk which consist of (1.21% and 68.32%) which is a total of 69.52%. this implies that the district is at high level of flood risk in the case of LULC criteria, whereas about 30.52% of the district has less chance to be affected by flood risks. Moreover, in the case of assessing the flood risk levels of the study area using soil, it is verified that 32.41% of the study area is at risk of flood. Regarding to the slope of a District, 58.95% of the area is laying at risk of flood, and for drainage density 20.97% of the area is at risk. As far as the elevation and rainfall criteria of the study area concerned, 39.77% and 16.66% respectively are found at high risk of flooding.

Generally, LULC shares the great values (35%), followed by slope, rainfall, soil, and elevation (58.95%), (39.77%), (32.41%) and (20.77%) respectively to evaluate the criteria independently. The amount of risk classes of the study area is quite different in different criterions, as a result of this, the study was applied the MCE methods to evaluate the flood risk areas by taking in to account to all criteria's base on their weights for causing flood.

4.7 Multi-criteria evaluation (MCE) Methods for Ranking and Weighting of Decision Factors for Flood

Analytical Hierarchical Process (AHP) is a decision-making technique which is used to solving of different and complex problems by integrating different methods (parameters) to meet the required objectives, Ryutaro (2014). But each parameter may not be equal in weight, and some parameters may invade the other. As a result of this, deep and expert based literatures are applied for using this approach to assess the flood risk problems in the study area. In addition to this, the nature of the study area has a great role in weighting and ranking of flood causative factors, so that the study area was considered in running weights. For this, selective key informants from Guba Lafto District agricultural and water resource office were organized and interviewed to rank the flood cause factors of the study area. Thus, LULC, soil, slope, rainfall, drainage density and elevation were applied as a parameter and the results are discussed in below.

As far as the significance of the parameters weight concerned, Eigenvector techniques were applied to give the weight of the standardized raster layers.

Table 4
Square pair wise comparison matrix of the criteria

Criteria	Rainfall	Soil	LULC	D. density	Elevation	Slope
Rainfall	1	1/3	1/7	4	1/5	¼
Soil	3	1	1/3	4	1/6	½
LULC	7	3	1	9	2	2
Drainage density	¼	¼	1/9	1	1/8	1/7
Elevation	5	6	½	8	1	2
Slope	4	2	½	7	½	1

According to the Nine-point pair wise comparison scale; 1 means, one factor is equally important to the other, 2 mean it is slightly moderately important than the other, 3 mean it is almost moderately important than the other and 9 means one factor (parameter) is extremely importance than the other factor in their relative weights.

Based on this, as the above table 4.3 indicates about the weight of parameters, soil is moderately important with rainfall factors, while LULC is very strongly importance than rainfall, but rainfall is strongly importance than drainage density and elevation. On the other hand, slope and elevation is strongly important than rainfall.

Table 5
Normalized Matrixes of the criteria

Criteria	Rainfall	Soil	LULC	Drainage density	Elevation	Slope	Weight	%
Rainfall	0.04933	0.02649	0.055215	0.12	0.05	0.04	0.057	5.7
Soil	0.1481	0.0794	0.129	0.12	0.04	0.08	0.1007	10.07
LULC	0.34	0.23	0.38	0.27	0.50	0.33	0.347	34.7
Drainage density	0.012	0.019	0.04	0.03	0.031315	0.024	0.0268	2.68
Elevation	0.24	0.476	0.193	0.24	0.250	0.33	0.2915	29.15
Slope	0.197	0.158	0.193	0.212121	0.125261	0.169	0.176	17.61
Grand Total	1	1	1	1	1	1	1	100

4.8 Calculating CR

The consistency ratio is computed with RI obtained from Pairwise comparison table. Hence, the result of CI is by far lower than the threshold value of 1.24 which is equal to 0.0. This implies there is a high level of consistency in the pair wise opinion and no need of reviewing the criteria since it is accurate.

4.9 Ranking Method

Inverse ranking method was applied for this study in order to rank the criteria consideration in addition to the factor maps. In the case of flood causing risk level, the list important is ranked as 1 while the most important criteria are ranked as 5. The eigenvector of the pair wise comparison matrix is used produce a best fit to the weight set. Weight values in this case refer to the priorities which are absolute numbers between zero and one. Their sum is equal to 1, and their weight is given with their perspective influence to flood occurrence.

A higher weight value of the factors represents more priority than the rest of the other factor. From the factor weights found for this study area, it is clear that the LULC characterized by different water holding capacity, have the highest weights, showed that LULC have more contribution to the occurrence flooding in the study area as compared to the other factors or elements followed by elevation and slope.

Table 6
summary of weighting of flood risk criteria

Decision factor	relative weight of each decision criteria	Decisions of sub factor ranking	Ranking
Rainfall (mm)	0.058	1.37862968-35.59924507-	5
		35.59924507–73.76876831	4
		73.76876831–113.895703	3
		113.8957031–162.8309892	2
		162.8309893–238.19133	1
Soil (type)	0.100	Cambisols	5
		Pheamosols	4
		Regosols	3
		Xerosols	2
		Leptosols	1
LULC (type)	0.347	Foerst land	5
		Shrub land	4
		Grass land	3
		Crop land	2
		Bare Land	5
Drainage density (Km)	0.026	0-0.69352	1
		0.69352–1.386504	4
		1.386504–2.079757	3
		2.079757–2.773009	2
		2.773009–3.466261	1
Elevation (M)	0.291	1,324–1,786	1
		1,786.000001–2,207	2
		2,207.000001–2,665	3
		2,665.000001–3,158	4
		3,158.000001–3,802	5
Slope (%)	0.176	0–10.25183632	1

Decision factor	relative weight of each decision criteria	Decisions of sub factor ranking	Ranking
		10.25183633–19.86293287	2
		19.86293288–30.75550896	3
		30.75550897–43.89067425	4
		43.89067426–81.69432068	5

The flood risk map in this study was generated by using the weighting and ranking technique. The nature of the method is solely depending up on the nature of the biophysical factors which are correlated with potential flood causing capacity. The factors were weighted according to their relative importance to each other and to their expected importance in causing floods. In addition to this, each factor was classified into five sub-factors, each of which was weighted and ranked. The higher-ranking values the higher susceptible to the occurrence of floods. LULC, Rainfall, elevation, slope, drainage density, and soil type decision parameters were identified as the most important factors for controlling the potential flood susceptible and its sub-factors as well as reclassification system was run depending on the previous flood related studies, (Tanavud et al., 2001).

Among all the six decision factors, a high weight was given for LULC followed by elevation, slope, soil type, and rainfall and drainage density.

Each of the six factors was further classified in to five classes based on their risk classes and given a ranking value accordingly. Finally, by using weighted overlay methods, it was reach to five categorical classes' very low, low, moderate, high, and very high.

Table 7
Final weighted overlay flood risk classes

No	Risk classes	Area coverage
1	Very high risky	5.76 (0.35)
2	High risky	25398.45 (25.58)
3	Moderately risky	61065.91 (61.41)
4	Low risky	12752.28 (12.81)
5	Very low risky	83.72 (0.08)
Grand Total		99306.09 (100)
Area coverage: number in ha; ( ) = % (percent coverage)		

As table 4.8 shows from the total land (99306.09 ha or 100 %), although there is a very small proportion of very high-risk areas (0.085) % of the total area, but there is a significant value of high risky 25398.45

ha (25.58) %. Those most risk areas are located in the central and eastern as well as south east parts of the study area. In addition to this, almost greater than a half 61065.91 ha (61.41) % is under moderately risky zones which are found in the central south and west parts of the study area including the northern regions. While the remains substantial area (12.81) % and very small area (0.08) % are low risky and very low risky respectively for flooding.

Based on the final weighted analysis of flood risk map of the study area, most highly flood risk kebeles were identified. 26064.29

Table 8
Potential identified high flood risk kebeles in Guba Lafto District

Kebeles	Area coverage
Gugsa	2184.57 (2.14)
Lasgerado	453.3 (3.41)
Hara	449.82 (0.45)
Lay Alhua	2939.13 (2.95)
Gubarija	3186.27 (3.2)
Shewit	4152.6 (4.18)
Sagat	5281.2 (5.31)
Gebre Amba	1569.6 (1.57)
Anova	2852.37 (2.87)

Area coverage: number in ha; ( ) = % (percent coverage)

32 kebeles in Gub Lafto District, nine kebeles were identified as the highest flood risk areas which consists of 26064.29 ha (26.25%) from the total 99306.09 ha (100%). From those high flood risk kebeles of the District, Sagat shewit, and Anova are found in the southern parts of the study area. Whereas Lay Alwha, Gebre Amba and Hara kebeles are located in the central part of the district. Moreover, the remain Gubajira, Gugsa and Las Gerado are found around in the eastern and north east part of the district. Generally, it was possible to identify the highest flood risk areas particularly the flood prone kebeles. The result shows that there are adequate flood prone areas in Guba Lafto District and the most sensitive areas to flooding were justified. The result also shows that one fourth of the study area (25%) is prone to flooding, which is very significant areas are under the risk of flooding. The identified prone areas are those which are bare lands, areas with low elevation and flatter slopes, closed to drainages and agricultural practiced area.

Conclusion

This research was basically intended to assess the potential flood risk areas to identifying the flood prone areas in Guba Lafto District, using GIS techniques with MCE methods. Pair wise combination methods of MCE enables to identify and rank the factors which control flood without biased and in a rational manner. Weighted overlay techniques on the other hand used to integrate all the factors to delineate and mapping appropriately.

As far as the LULC of the study area concerned, the result shows that there are basically five different LULC types are available, but the majority of the study area is covered by crop lands 68.32 % followed by shrub, grass land, forest and grass land (18.23 % 7.47 %, 5.91 % and 1.21 %) respectively. This implies, since agricultural land can easily vulnerable for flooding due to its low flood resistance capacity, a significant portion of the study area is at risk.

The study also shows that slope, LULC, elevation soil type, drainage density and rain fall is the dominant cause of flooding for Guba Lafto District. Moreover, based on their weight for flood risk, LULC takes the great share (35 %) for flood cause next to elevation and slope (29% and 17%) as it is explained in the discussion parts.

Furthermore, the main findings of the results also prevail that, Guba Lafto woreda is mainly ranges from high, to moderate and low flood risk zones (25.58%, 61.41% and 12.81 %) respectively. Only small areas are within a very high risk and a very low risk (0.35% and 0.08%) respectively. As the final potential flood risk map of Guba Lafto District shows, most high-risk areas are found in the east and south part of the study area. While the central and western part of the area is ranging from moderate to high flood risk zones. This is because of their topographic features and their nearest to the stream basins as well their land use type. It is possible to see which area is within a low to high flood risk zone using GIS techniques with MCE methods for taking effective measures to any decision-making authorities. Apart from this, GIS techniques has a good potential for identifying and delineating of flood risk areas, while MCE is very easy, flexible and clear way of prioritize and weighting of the flood decision parameters.

Declarations

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Ethics approval and consent to participate: NA

Data Availability: The authors affirm that raw or processed data which support the findings of this study cannot be shared at this time due to time limitations and will be shared upon reasonable request of the corresponding author.

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Figures

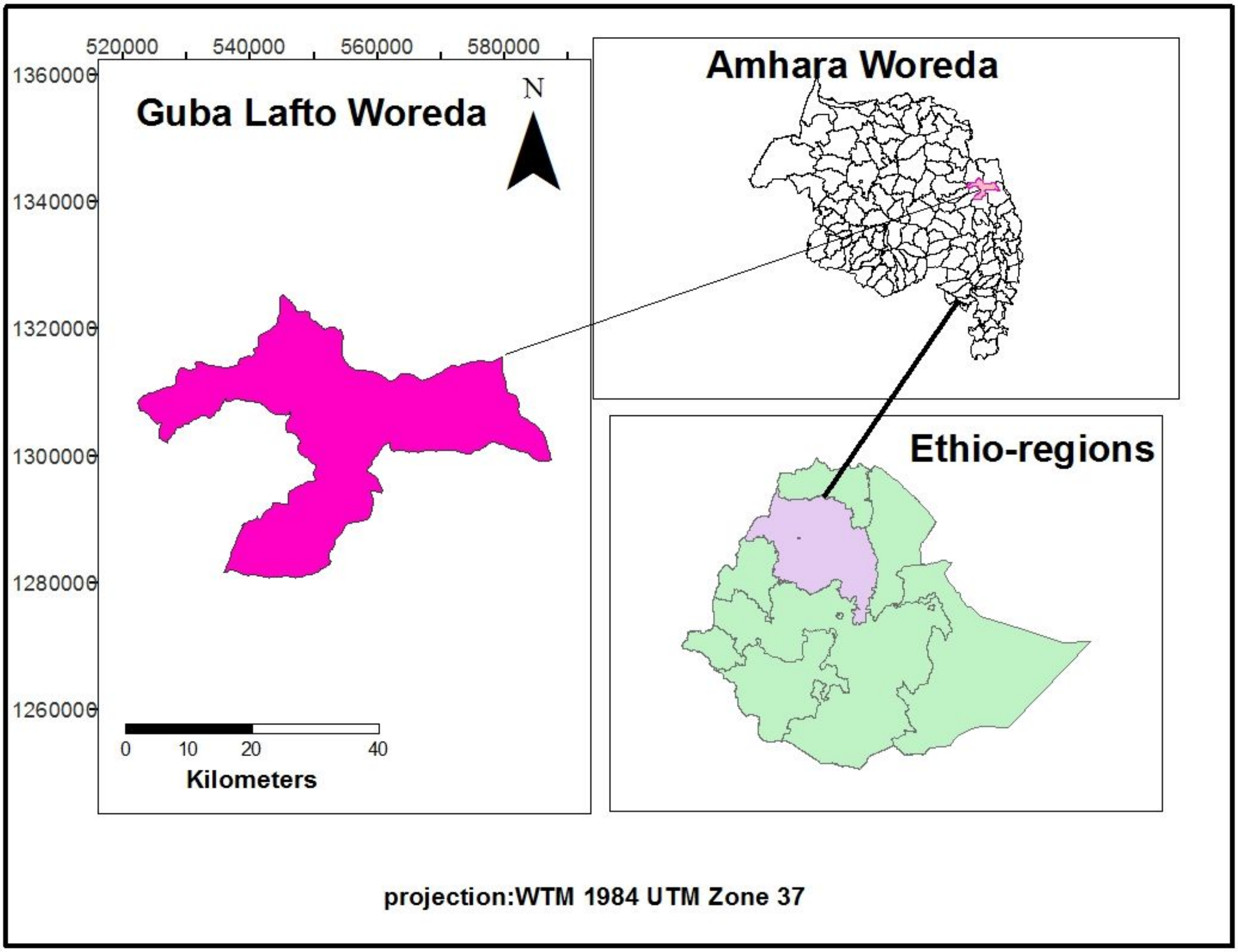

Figure 1

Map of the study area

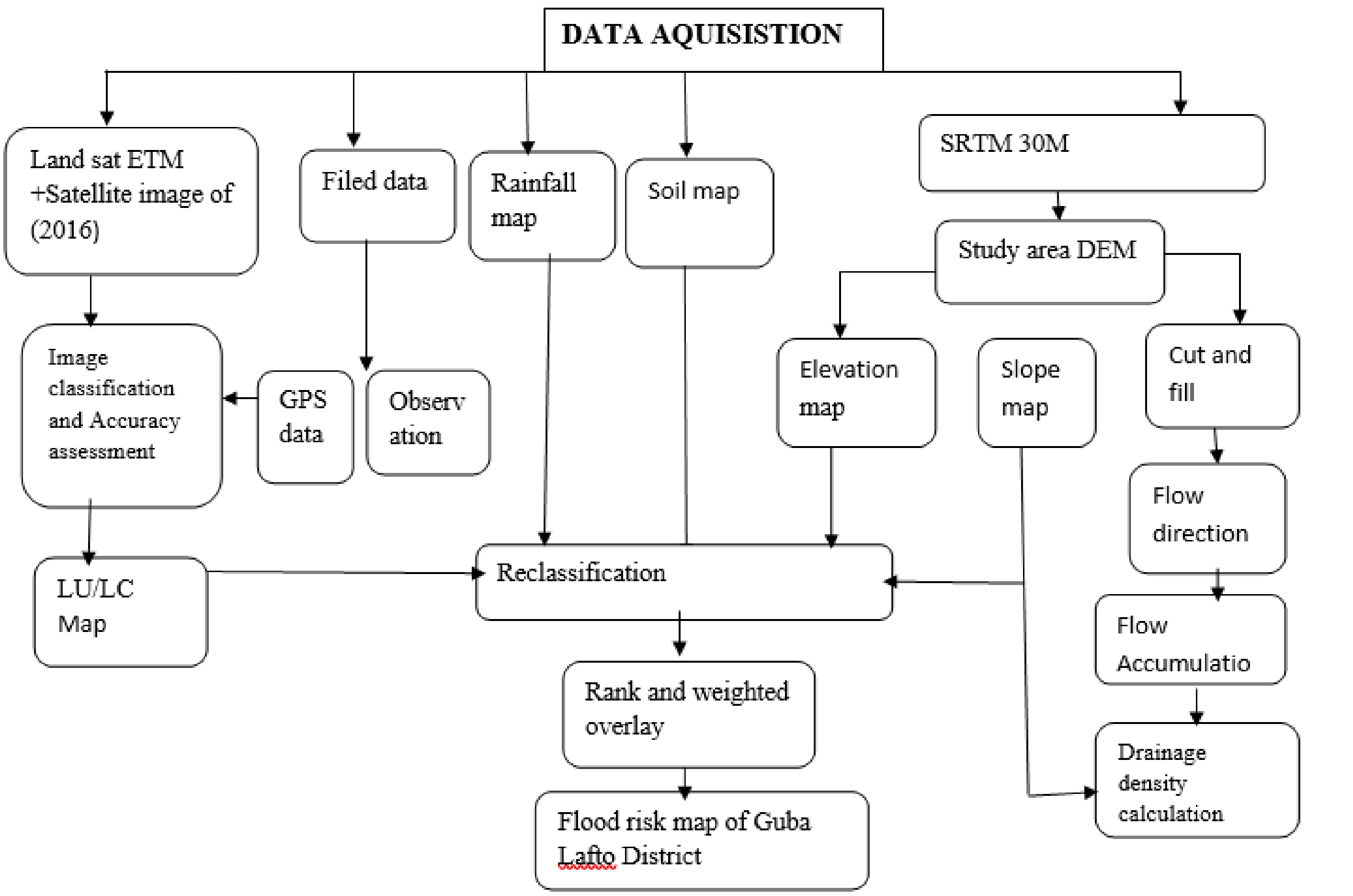

Figure 2

Flow charts of the methodology

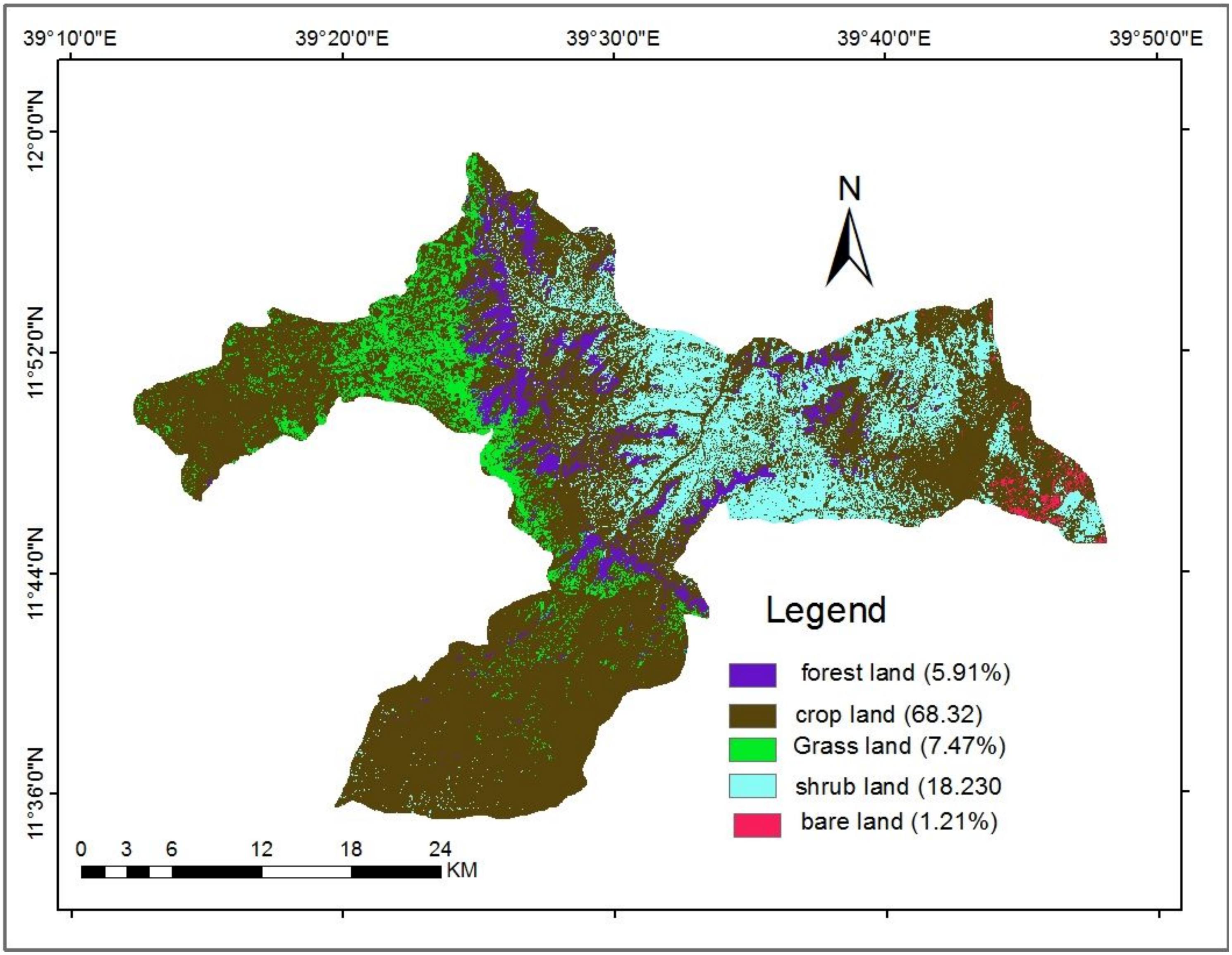

Figure 3

LULC map of Guba Lafto District

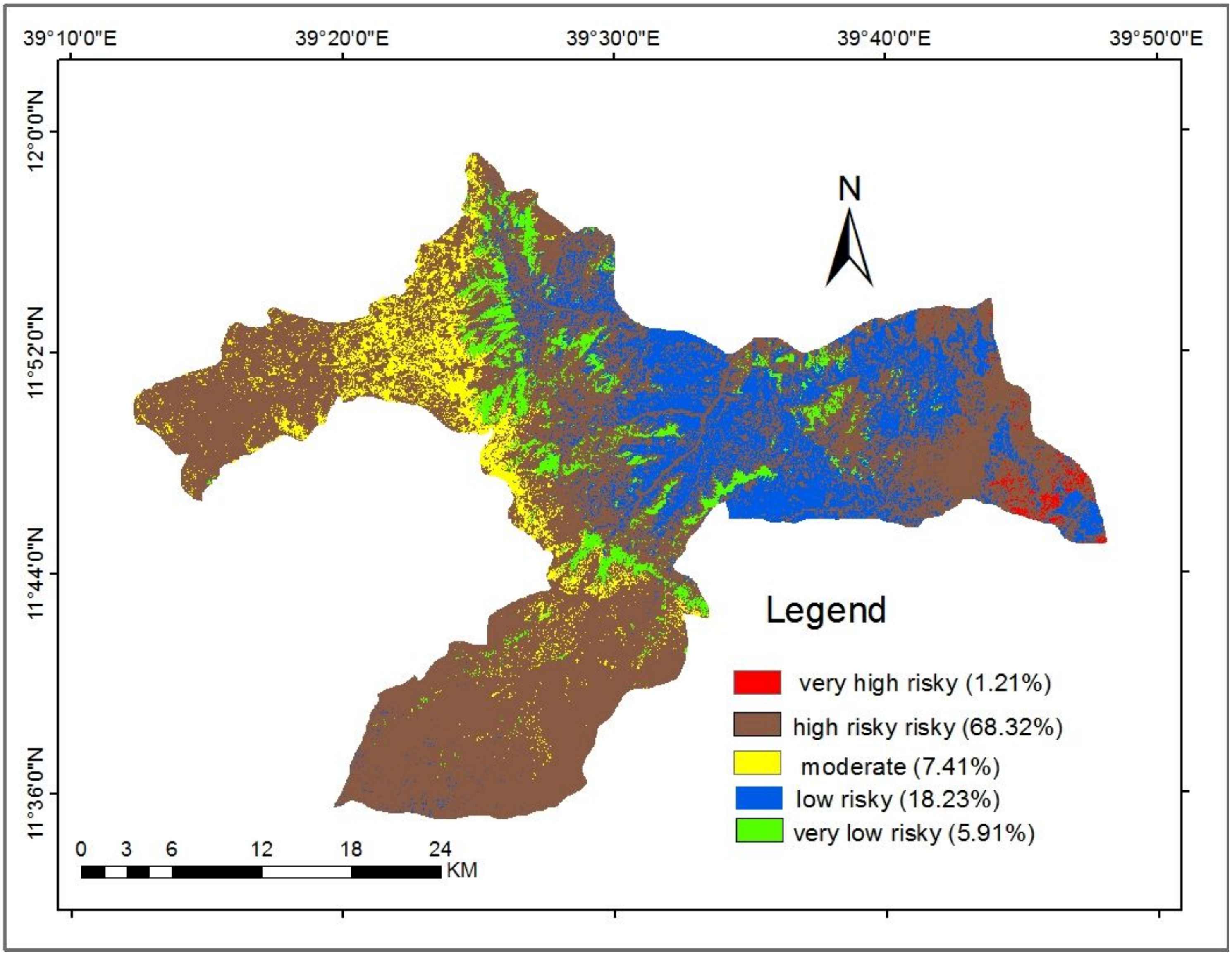

Figure 4

LU/LC flood risk map of the study area

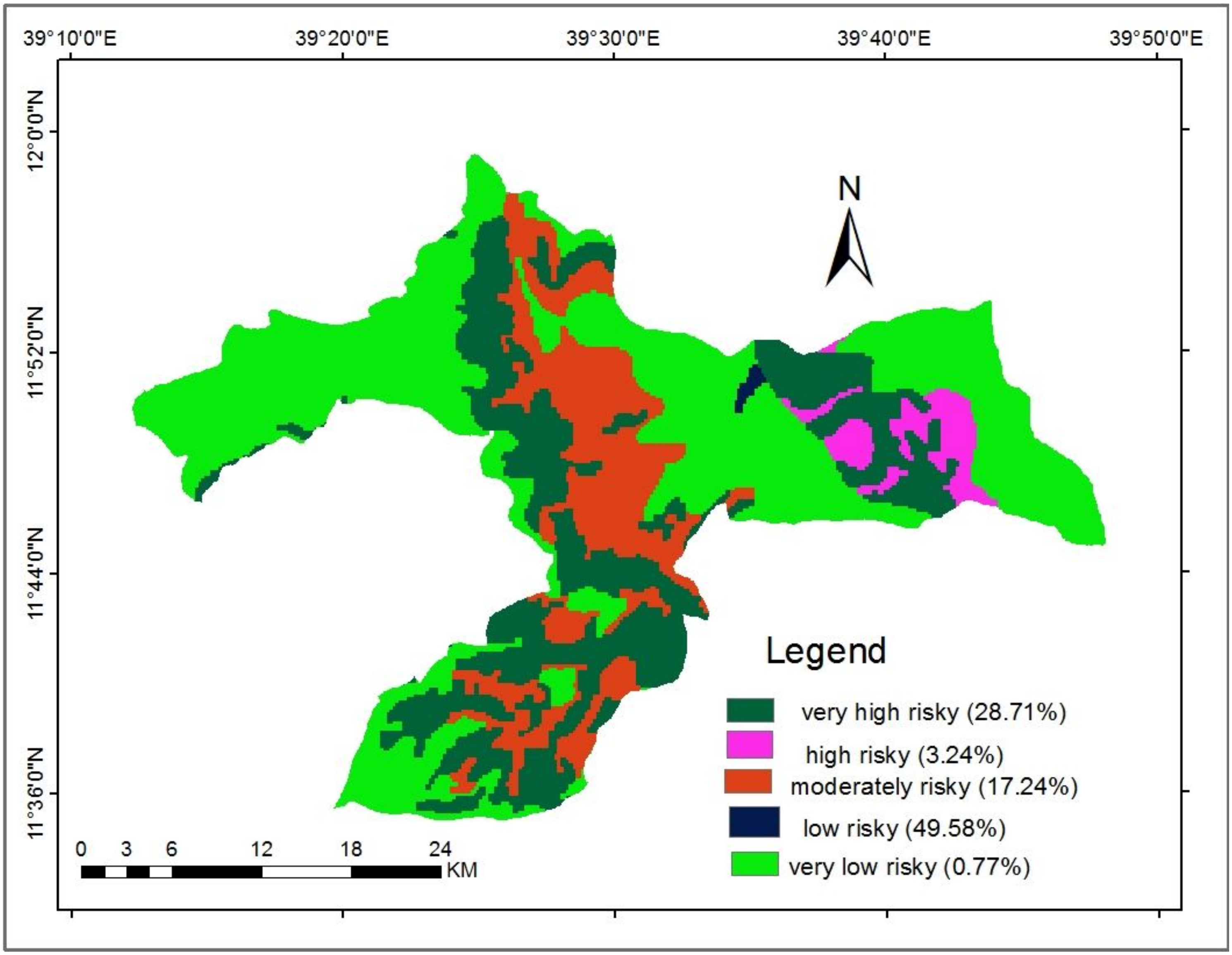

Figure 5

soil type factor map of the study area

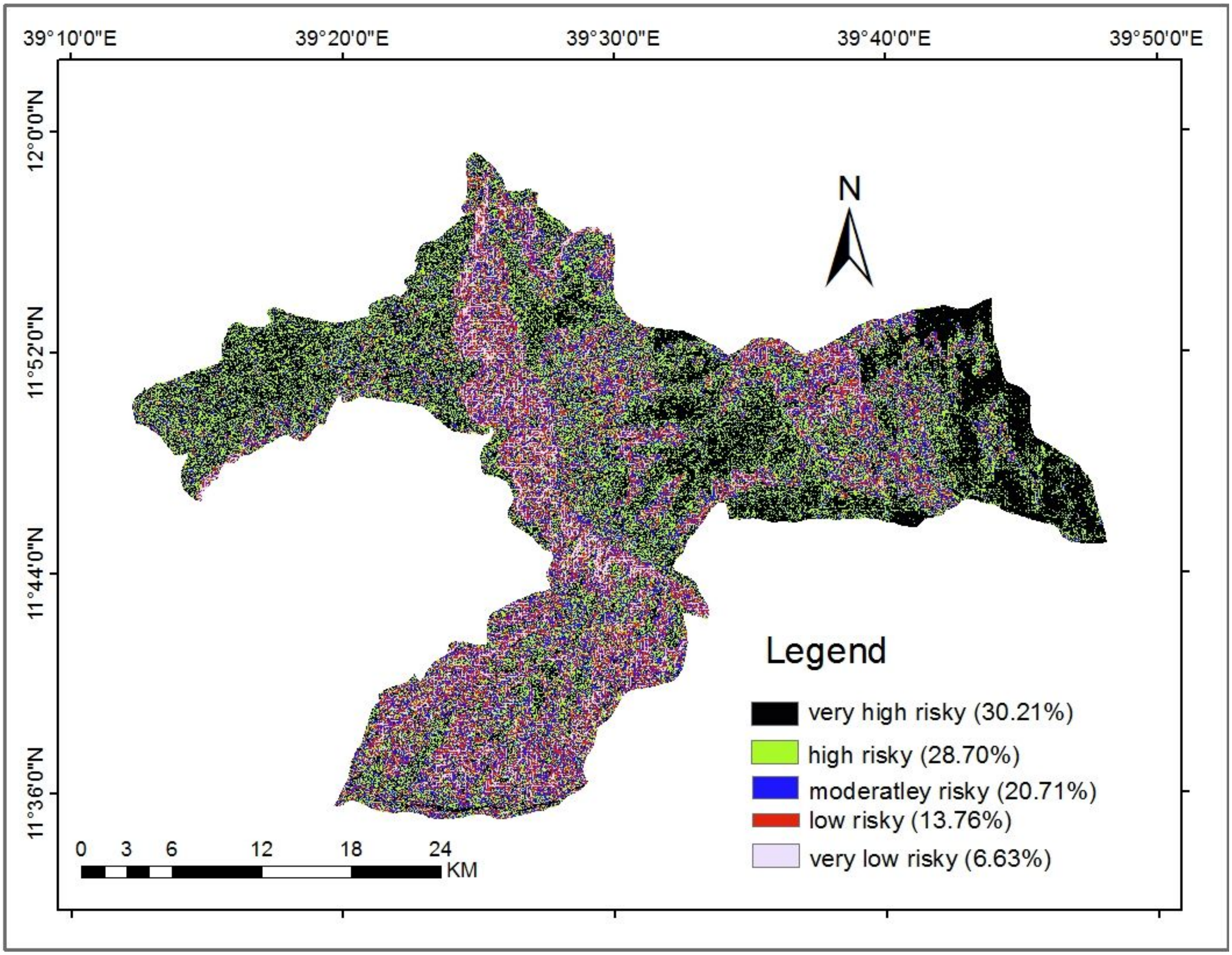

Figure 6

slope factor map of the study area

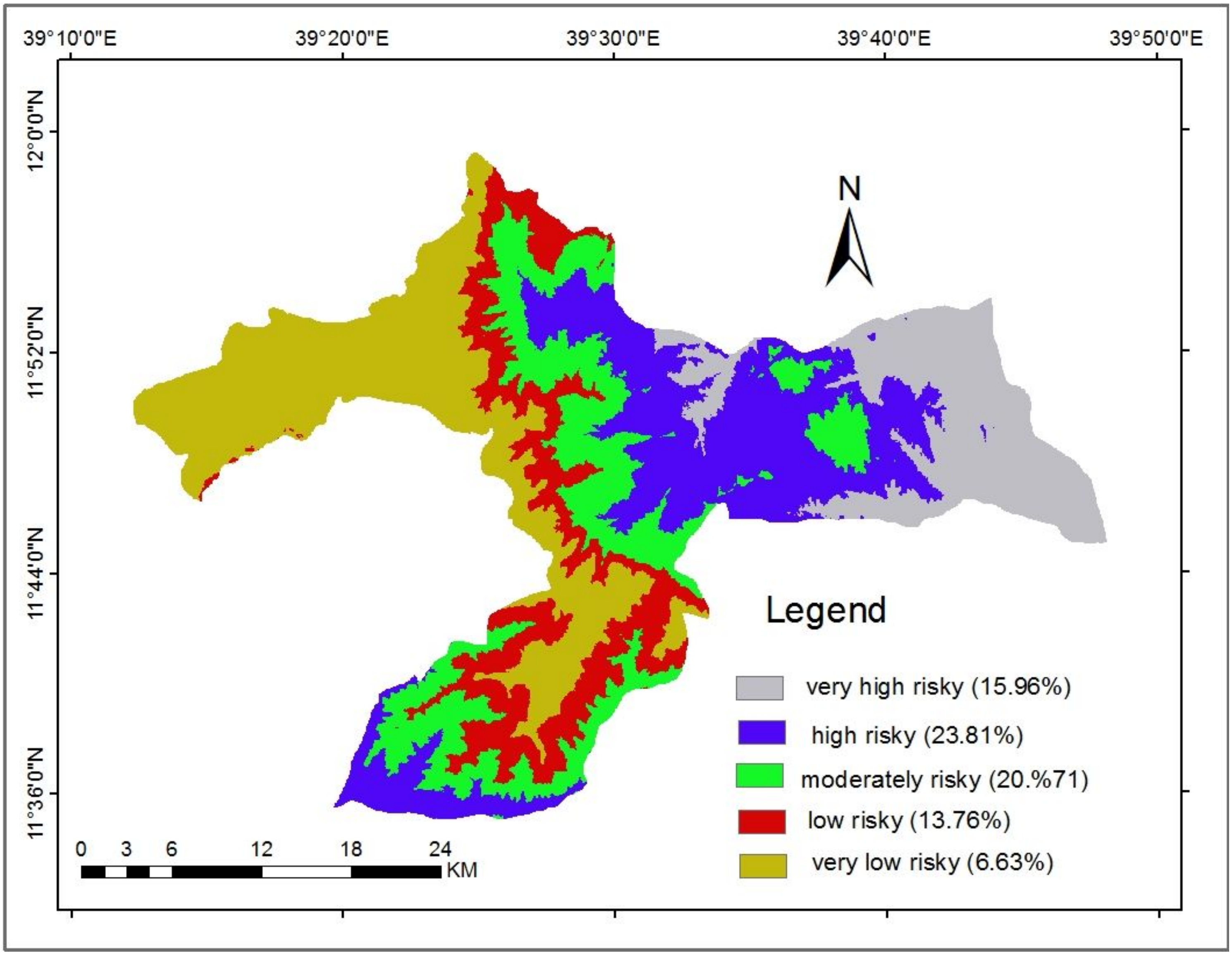

Figure 7

elevation risk map of the study area

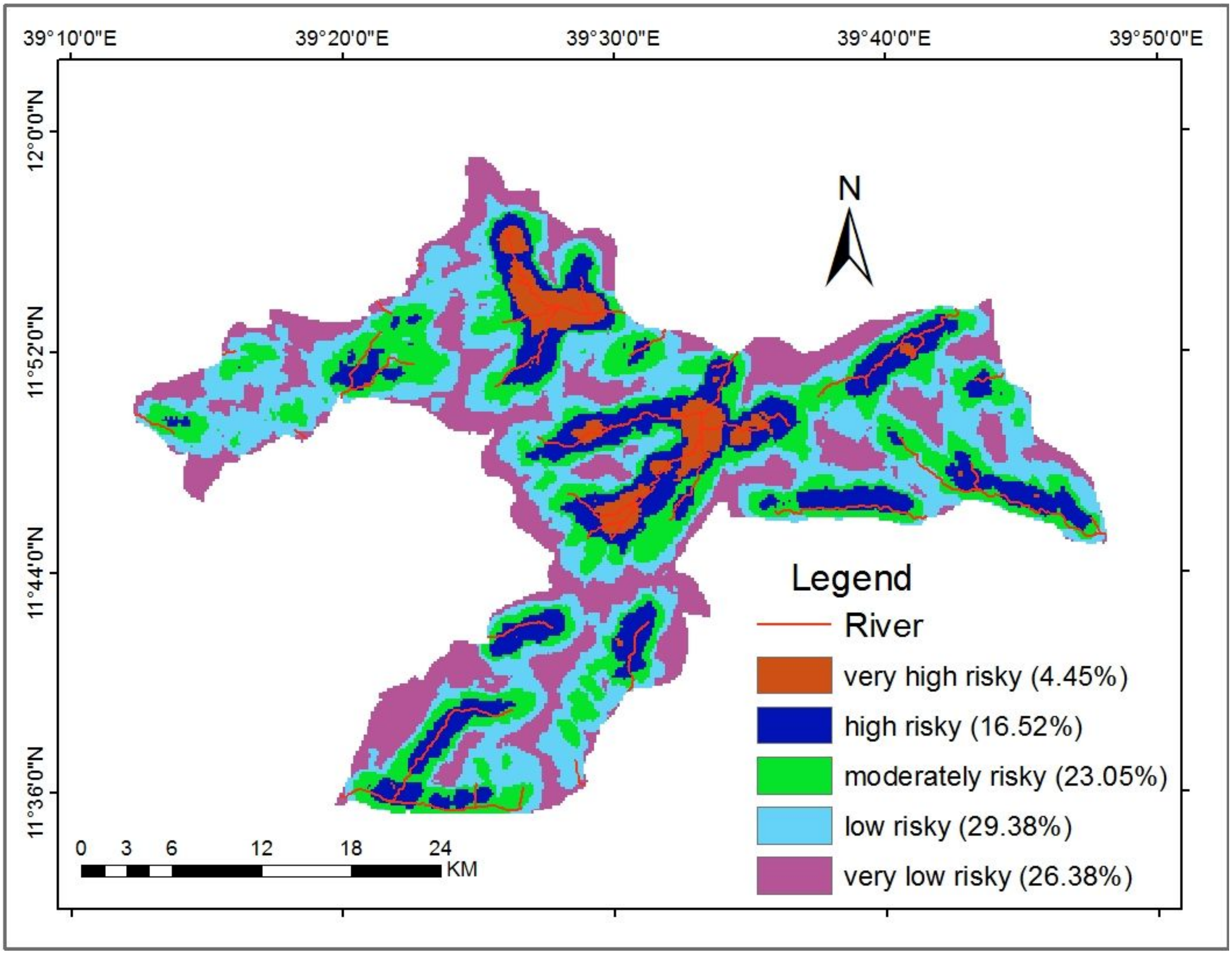

Figure 8

drainage density factor map of the study area

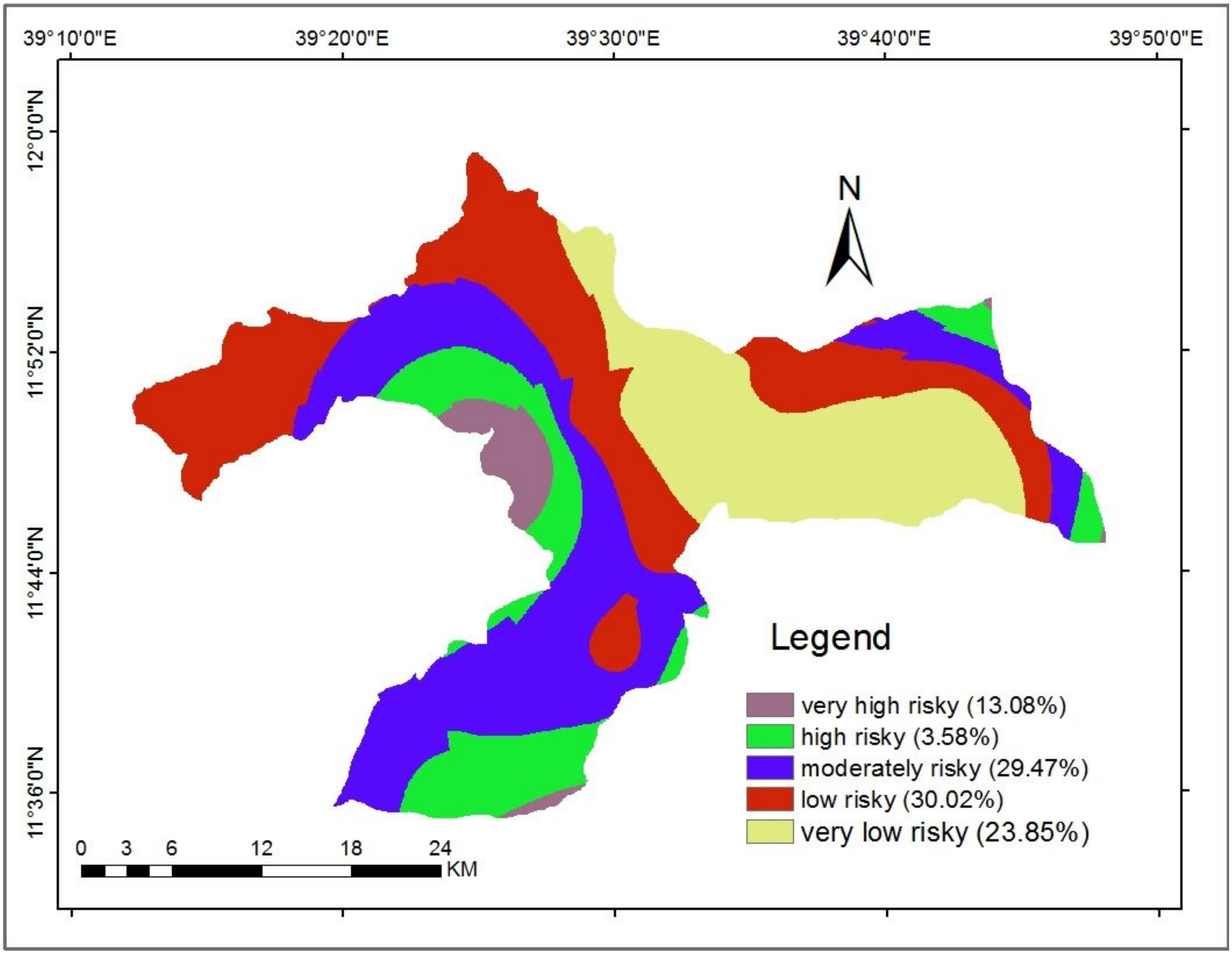

Figure 9

rainfall factor map of the study area

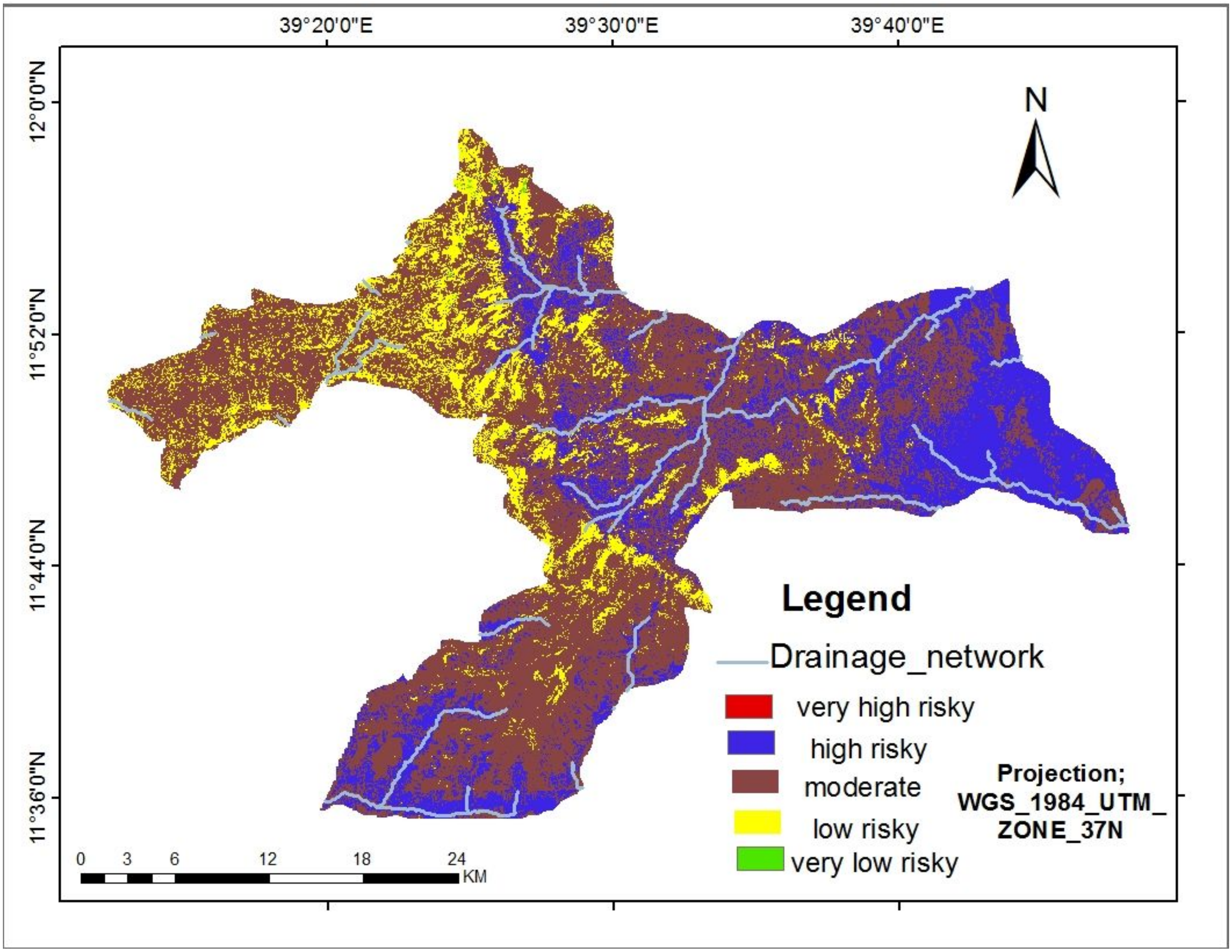

Figure 10

potential flood risk map of Guba Lafto District