Flood Vulnerability Modeling Using GIS and Remote Sensing: The Case of Shashogo District, Hadiya Zone, Southern Ethiopia

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Abstract
River flood is one of the natural hazards that have negative impacts on population and property. It occurs in the lower course of a river when excessive rainfall occurs in upper course of adjacent highlands. Since flood is unavoidable natural phenomena, adopting mitigation measures are crucial. This study was conducted in Shashogo district of Southern Ethiopia with the objective of identifying and mapping flood vulnerable areas. For this purpose the following data mentioned below wereused. Ground Control Points (GCP)were collected from Google earth, Digital Elevation Model (DEM) and Landsat 8 down loaded. Besides, data such as, soil data, rainfall, and population data were collected from different institutions. Flood vulnerability factors namely slope, distance to rivers, elevation, rainfall, drainage density, land use/ cover and soil type were generated. In order to map flood vulnerable area, Geographic Information System (GIS), Remote Sensing and Analytical Hierarchy Process (AHP) were used. AHP was used for computing weight for the parameters by comparing seven factors. The weight derived for slope, drainage density, distance to river, land use land cover, rainfall, elevation, and soil type, are: 21%, 18%, 15 %, 13%, 12%, 11% and 10%, respectively. The consistency ratio was less than 0.1(CR - 0.6) which is acceptable weight to compute weighted overlay analysis in GIS environment. The result shows that a different degree of flood vulnerability at different locations in Shashogo district was found. The map indicated that the degree of flood vulnerability scale varies from very low vulnerable to very high vulnerable. From the total area of 358.1 Km^2 0.28 % and 47.98% of the study area was found in very high and high vulnerable to flood respectively. Especially the central parts of the study area surrounding Lake Boyo were highly vulnerable for flooding. Since flood cannot be avoided totally, it is better to take mitigation measure in order to reduce the flood vulnerability of the society. It can be generalized that to reduce flood vulnerability using nonstructural method like early warning and flood vulnerability map to development of protection structure is important with integrated watershed management method to reduce flood vulnerability effectively.
Keywords: Flood vulnerability, GIS, Remote Sensing, Multi-Criteria Evaluation, and Analytical Hierarchy Process.
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1. INTRODUCTION
A flood is a natural phenomenon that leads to temporary submerging of a piece of land with water that does not occur under normal conditions (EC, 2007). Flood damage constitutes about a third economic losses imposed by natural hazards worldwide after earthquake and tsunami (Winsemius *etal.*2013). The major environmental disasters in Africa are recurrent droughts and floods (Nicholls, 2004). Between 2000 and 2008 East Africa including Ethiopia has experienced many episodes of flooding (OFDA/CRED, 2008). Ethiopia's topography characteristics has made the country vulnerable to floods and resulting destruction and damage to life, economic, livelihoods, infrastructure, services and health system (FDPPA, 2007).

In Ethiopia river flooding and damage occurrence are common. These types of flooding happen at the time of rainy season when rivers overflow their banks and engulf downstream plain lands of right or left sides along the river. Many parts of Ethiopia are affected by river flooding in the past years. For instance, flooding of Awash River, Omo River, Rib and Gumera River, Dechautu River flooding are some of incident happened in Ethiopia (Daniel, 2007; Woubet, 2007; Sifan, 2012).Flooding in Ethiopia is getting more and more acute due to human intervention in the fragile highland areas at an ever-increasing scale. Sothern nation nationalities (SNNPR) including the study area was seriously affected by flooding (DPPA, 2006). River flooding is the main natural phenomena, which annually cause loss of lives and damage to property including displacement during the rainy season in Shashogo district. In July 2016, due to overflow of Bilate (Wera), Guder rivers and backflow of Lake

Boyo, have made many people displaced from their homes, suffered from shortage of food, and exposed for water and vector-borne diseases, Example cholera, malaria.

The Bilate River flooding affected the Shashogo District of southern Ethiopia in 1997, 2002, 2008, 2010 and 2016(SWANRDO, 2016). For minimizing the hazard or losses due to floods, local people were using traditional method such as terracing and opening ditch manually. Flood control and mitigation measures can be planned either through structural measures or non-structural measures. Wise application of controlling mechanism has afforded many ways of mitigating the damage and providing reasonable measure of protection to life and property (Mogos and Carlo-s, 2007). Generally, some of flood control and management method were carried out by integration of community participation where the people live near the river bank of the Bilate River in Shashogo District. However it is impossible to avoid flooding and its damage, developing mitigation measures are crucial. For this purpose, it is important to focus on identifying and mapping flood vulnerability using GIS and Remote Sensing.Although it is impossible to avoid floods totally but it can be mitigated through structural and non-structural methods. Structural method have not been proved to be effective in the long run whereas the non-structural measures such as vulnerability mapping and early warning system prove to be quite effective in reducing losses from floods (Sisir and Batal, 2014).There are various research initiatives conducted to deal with this issue in the Awash River Basin (Daniel, 2007; Kebede, 2012; Sifan, 2012; Getahun and Geber, 2015).

However, there are no studies conducted in the Bilate watershed of Shashogo District related to flood prone area mapping and mitigation measures. In the present study, the researcher attempted to identify and map flood vulnerable areas for the District using GIS and Remote Sensing.The overall objective of this study was to identify the Flood prone area in Shashogo District using GIS and Remote Sensing. Specific objectives were outlined.(1). identify factors controlling flood vulnerability in the Shashogo district (2). Develop flood vulnerability map of the Shashogo district. (3). Suggest mitigation measures for the recurrent flood vulnerability.

2. MATERIALS AND METHODS

2.1. Description of Study Area

2.1.1. Location

This study was conducted inShashogo district. The district is found in Hadiya zone, Ethiopia. It is locatedabout 117 km from Regional capital Hawassa and 224 km far from Addis Ababa. It is part of the Bilate sub basin. Geographically, it lies between 7°24´ and 7°40´North and 37°54´ and 38°12´ East (Figure.1).The area covers 358 .1km^2. The Shashogo district is upper apart of Bilate sub-Basin, whose tributaries originate from the upper Escarpments of Hadiya, Silite, and Guraghe highlands.

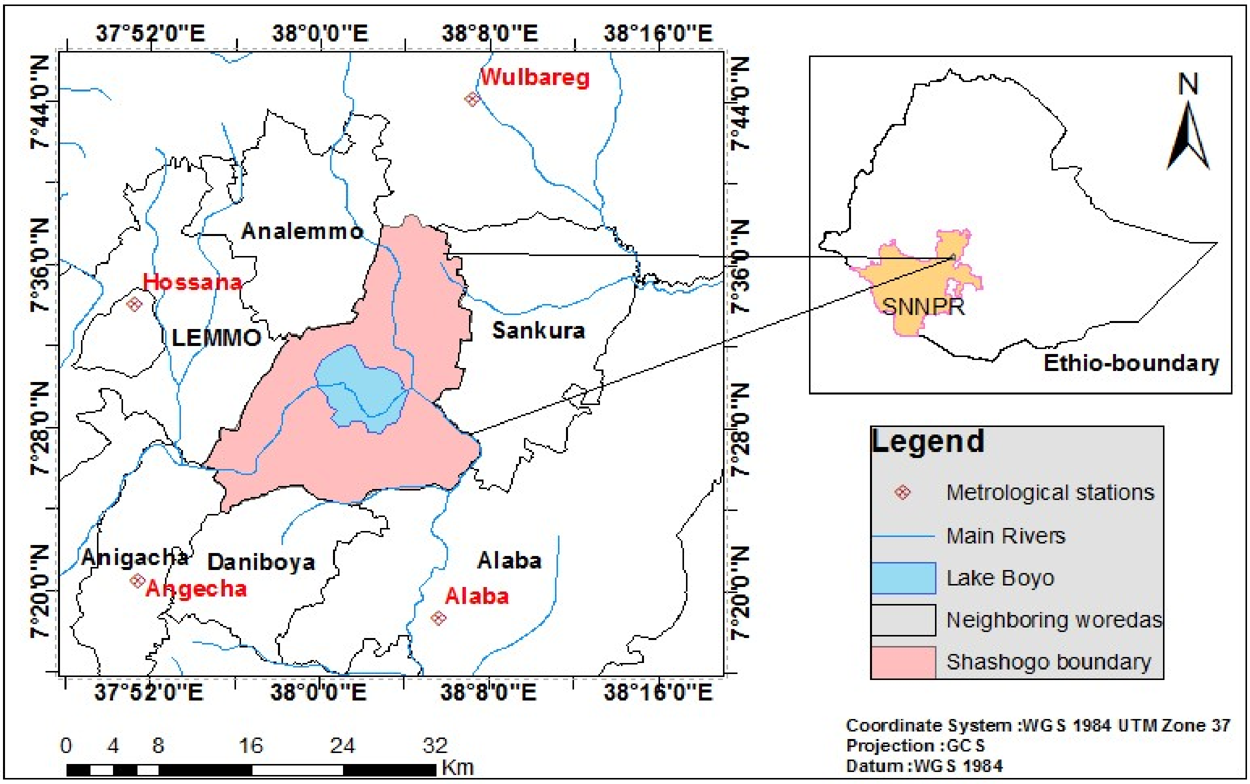

Figure 1: Location map of the study area

2.1.2. Demographic characteristics.

The population of Shashogo district was estimated about 103,722(CSA 2007).In 2016 population of the Shashogo has been estimated about 128157 (CSA, 2016).The population density of the study area varies from167 person/km2 to514 person/km but the average density is 289.65km2. From total population 52,435 are male and 51,287 Female.

2.1.3. Climate and Elevation

Agro-ecologically the district is fully characterized as arid woyina dega (semi-arid) in which its altitude ranges from 1173.a.s.l to 2200. Agriculture is the main economic activity and livelihood strategy for smallholders in Shashogo district which involves more than 85 percent of the population. From the total population, 26% of them were living in flood susceptible areas.

The rainfall data collected by the nearby Ethiopian Meteorological Agency (NMA) from Alaba, Wulbarege, Angecha and Hossana Stations, which are not more than 30 km far from the study area, were used to describe the climate of the study area. The rainfall has a bimodal nature in which the months from March to May and June to September are marked by relatively higher rainfall records; while months from November to February are dry. The long rainy season in the area is between Junes to September. The long term annual (1997 -2016) mean rainfall of study area is 1172.06mm. There are about four rainfall observation stations around the district (Fig: 1). Time series rainfall data of these stations was obtained from the National Meteorological Agency (NMA) of Ethiopia. The selected stations with their mean annual rainfall value for the 20 years period under study are summarized in (Table: 1)

Table 1: Location of rainfall stations in the study area from 1997- 2016

Name of the station	Average annual Rain fall	Latitude	Longitude	Elevation
Alabakulito	1028.2	7.310585	38.09392	1772
Angacha	1418.2	7.3405	37.8572	2317
Hossana	1225.2	7.5673	37.85383	2307
Wulbarege	1055.4	7.73633	38.12033	1992

Mean monthly Rainfall data of twenty years (1997 -2016) collected from nearby four Metrological stations indicated that the main rainfall season of the study area was from July to September and the year 1997 ,2002,2008 ,2010 and 2016 had have relatively high rainfall records.

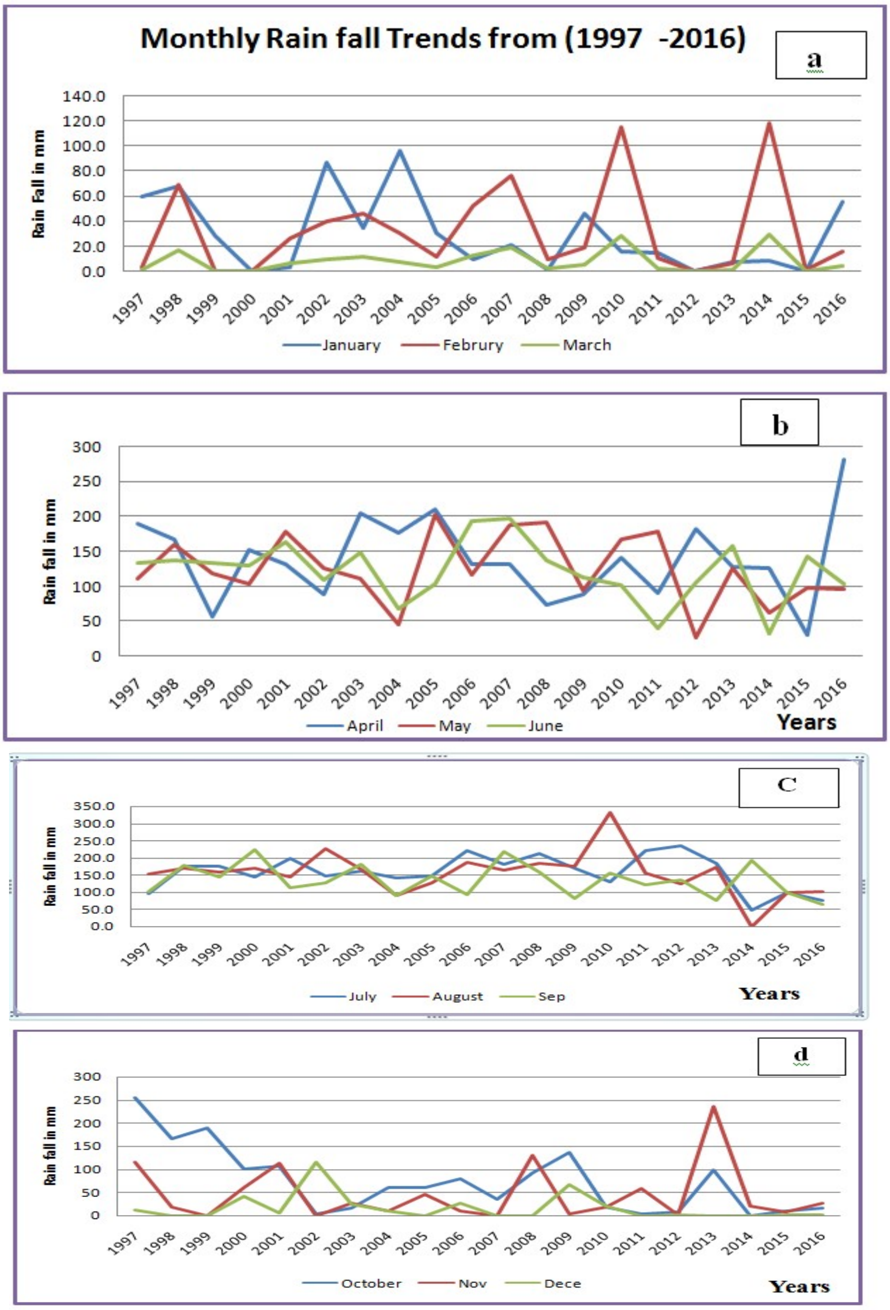

Figure 2: Mean Monthly rainfall trends form 1997-2016 (a-d)

The elevation of the study area ranges from 1173.a.s.l to 2200 a.s.l.The study area has diversified nature of topography, ranging from very flat to rugged topography. The lowest elevation is at the south eastern part of the area, situated in the main Ethiopian Rift valley at the border of Alaba special woreda. Slope of the study area is ranging 1% between 69% but the dominant slope of the area was between 1%- 2%.Generally, the elevation decrease from west to east. Due its flat topography, the study area is prone to flooding during rainy season and affected by erosion deposition at the center.

2.2. Method

2.2.1. Source of Data

Table.2: Data types, sources and resolutions

NO	Type of Data	Source	Resolution(m)	Remark
1	Digital elevation model	SRTMhttps://www2.jpl.nasa.gov/srtm	30*30	
2	Rainfall	NMA 1997-2016	30*30	Resample
3	Landsat 8,2018	https://glovis.usgs.gov	30*30	original
4	Soil Data	(MoWIE,2016)	30*30	Resample
5	Populations Data	(CSA,2007 and 2016)		
6	Distance to the River	Extract from digital elevation model		

2.2.2 Material and Software to be used

Thefollowing software and equipment were used for in the process of analysis and generating Flood vulnerability map, these include: ERDAS IMAGINE 2014, Arc Map10.3.1, AHP and Google earth was used for collection of ground control points to validate for land use / cover map.

Table 3: The types of Software and their application area

No	Software and Material to be used	Major application Area
1	Arc Map 10.3.1	thematic map generating, Reclassification, Area Calculation, map lay out and weighted overlay, accuracy
2	ERDAS IMAGINE 2014	Image processing and Land use/ cover classification
3	Microsoft Excel	Rainfall data Analysis, Interpolation and to calculate Return period and Probability of occurrence of flood.
4	Google earth	Ground truth for land use/cover classification
5	AHP	To compute weight for factors

2.3. Method for Flood Vulnerability Modelling

Vulnerability maps can be utilized in all steps of disaster management: prevention, mitigation, preparedness, operations, relief, and recovery (Edwards *et al*., 2007). Thus, the vulnerability map can be used for land use planning. Integrating the GIS, Remote sensing data, and AHP are quite effective tools to generate flood vulnerability data for flood prone areas. The overall method description for flood vulnerability was explained in Figure: 3 below. There are seven physical parameters for flood vulnerability utilized in this study, namely, slope, drainage density, distance to river, land use land cover, rainfall, elevation and soil. By integrating all of those components, the flood-vulnerable area was mapped. The methods for this research work include the following stages: i), data collection, ii) identification and evaluate of factors and preprocessing; iii) Reclassified input datasets iV) Pair wise comparison of criteria and give weight with (AHP); V) Overlay analysis with Weight sum overlay analysis in Arc GIS tools, ranking the final Value.

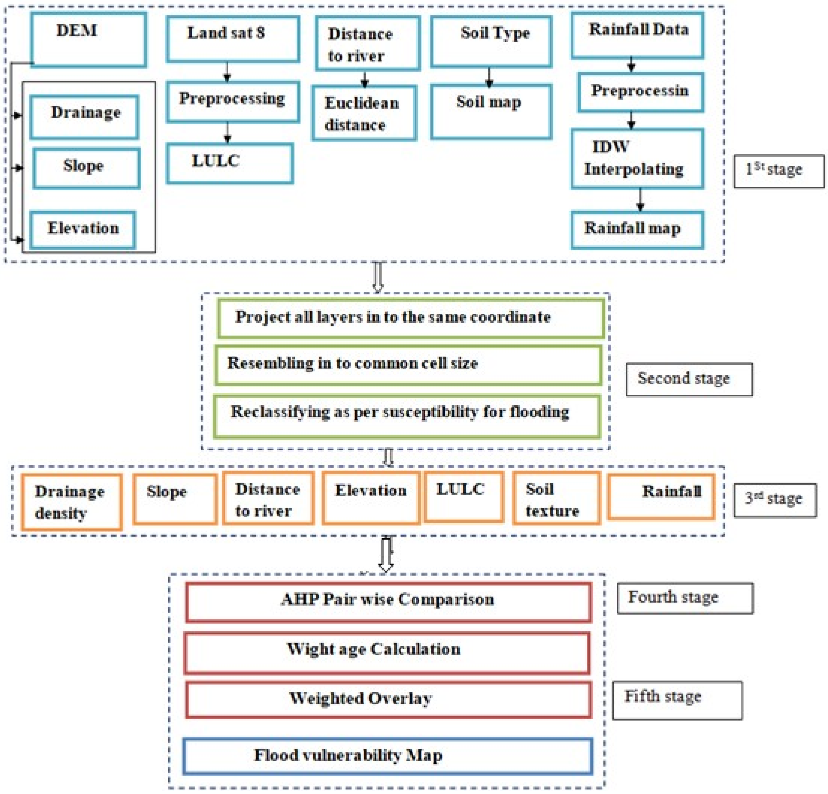

Figure 3: methodological frame work for flood vulnerability modeling.

Table 4: AHP Scale of Relative Importance

Relative Importance	Definition	Explanation
1	Equally important	Two factors contribute equally to the objective.
3	Moderately more important	Experience and judgment slightly favor one over the other.
5	Strongly more important	Experience and judgment strongly favor one over the other.
7	Very strong more important	One parameter is favored very strongly s and is considered superior to another; its dominance is demonstrated in practice
9	Extremely importance	The evidence favoring one parameter as superior to another is of the highest possible order of affirmation
2,4,6,8	Intermediate values	When compromise is needed.
Reciprocals of above	If an element *i* has one of the above numbers assigned to it when compared with element *j*, then *j* has the reciprocal value when compared with *i*	

2.3.1. Ranking of flood vulnerability parameters

Table 5: Comparison Matrix

Criteria	Slope	Soil	Drainage	Rain fall	Elevation	LULU	Distance to river
slope	1	2	1	2	3	4	5
Soil	1/2	1	1/2	1	3/2	2	5/2
D.den	1	1/2	1	2	3	4	5
Rain fall	1/2	1	2	1	3/2	2	5/2
Elevation	1/3	3/2	3	3/2	1	4/3	5/3
lulc	1/4	2	4	2	4/3	1	5/4
distance	1/5	5/2	5	5/2	5/3	5/4	1
Sum	3.8	10.5	16.5	12	12.9	15.6	18.9

Table 6: Weight Normalization matrix

	Slope	Soil	D.D	Rf	Elev	lulc	Distance to river	priority Weight	%
Slope	0.26	0.19	0.06	0.16	0.23	0.26	0.26	0.201	21%
Soil	0.13	0.09	0.03	0.08	0.12	0.13	0.13	0.101	10%
DD	0.26	0.05	0.06	0.16	0.23	0.26	0.26	0.182	18%
RF	0.13	0.09	0.12	0.08	0.12	0.13	0.13	0.114	12%
Elev	0.08	0.14	0.18	0.13	0.07	0.08	0.08	0.108	11%
lulc	0.06	0.19	0.24	0.16	0.11	0.06	0.06	0.125	13%
Distance to river	0.05	0.24	0.30	0.21	0.13	0.08	0.05	0.151	15%
sum	1	1	1	1	1	1	1	1	100%

Note that: the weight value represent the priorities which are absolute numbers between 0 and 1. The eigenvector is an estimate of the relative weights of the criteria been compared. Because individual judgment will never agree perfectly the degree of consistency achieved in the ratings is measured by a Consistency Ratio (CR) it indicates the probability that the matrix ratings were randomly generated. The rule of thumb is that a CR less than or equal to 0.1 .reciprocal matrix, a ratio over 0.1 indicates that the matrix should be revised.

Table 7: Random Consistency Index (RI) (Saaty, 1980).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Checking for Consistency.

Consistency ratio is indication of acceptability of reciprocal matrix, which calculated as the following

$$CR = \frac{CI}{RI} \ldots\ldots\ldots\ldots\ldots\ldots \text{(Equation 4)}$$

$$CI = \frac{(\lambda max - n)}{(n-1)} \ldots\ldots\ldots\ldots \text{(Equation 5)}$$

RI=Random consistency index

n=number of criteria.

λmax, = is Σ of the products of each element of the comparison matrix and priority weight, also the sum divided by the weight of consistency vector.

Based on the computed AHP value CR is lower than the threshold value of 0.1(CR= -0.6) and indicates a sufficient level of consistency in the pair wise judgments, and implies that the determined weights are acceptable. Each factor was prepared for the weighted overlay in Arc GIS with Weighed Linear Combination method (WLC).

2.3.2. Ranking Method and weighted overlay

To generate criterion values for each evaluation unit, each factor weighted according to estimated significance for causing flood. There are two ways of doing this; straight ranking (very high vulnerable =5; high vulnerable = 4; moderately vulnerable =3; low vulnerable =2 and, very low vulnerable = 1).

The factor maps depicting different Food vulnerability Level are overlay on Arc GIS 10.3.1. These thematic Layers are such, as; slope, drainage density, distance to river, land use / cover, rainfall, elevations, and soil type, are reclassified and computing weigh based on their influence on susceptibility on flood.

Table 8: Weigh assigned for each Flood Vulnerability factors

Factor	Relative weigh	Sub factor	Ranking Decision
SLOPE (%)	21%	0 -2 % 2-4 % 4 -8 % 8 -16% 16 -30%	5 =very high 4 =high 3 = Moderate 2 = low 1 = very low
Drainage density(m/m^2)	18%	0 -0.7 0.7 -1.4 1.4 - 2.1 2.1 -2.8 2.8 -3.5	1 =very Low 2 =Low 3 =moderate 4=High 5 =Very High
Distance to river	15%	0-200 201-400 401-600 601-800 >800	5 =very high 4 =high 3 =Moderate 2 = low 1 =very low
LULC	13%	Settlement/marshy land Crop land Bare land Grass land Vegetation	5 =very high 4 =high 3 =Moderate 2 = low 1 =very low
Rain fall(mm)	12 %	1320.96 -1244.18 1244.18-1201.97 1201.97-1166.79 1166.79 -1135.14 1135.14 - 1096.44	5 = very high 4 =high 3 =Moderate 2 =low 1 =very low
Elevation(meter)	11%	1773 -1868 1868 -1910 1910 -1958 1958 -2032 2032 -2200	5 =very high 4 =high 3 =Moderate 2 =low 1 = very low
Soil Type	10%	Chromic Vertisols Vitric Andosols Pellicvertisols Sand mixture Solonchack/Leptosols	5= very high 4 = high 3 = moderate 2 = low 1 = very low

3. RESULTS AND DISCUSSIONS
3.1. FACTORS INFLUENCING FLOOD VULNERABILITY
3.1.1. Slope and Flood vulnerability
Different areas in the Shashogo district fall under different slope categories; flat, level, gentle, steep or very steep. The majority of the area falls within a level- areas falling 0 - 2%, (50 %) which was ranked “very high”and (18 %) of the study area are found in the high flood prone area. The rest (32 %) of the study areas were categorized at the slope range between 4 % -30 % which are considered as moderate to very low steepness, Storm water also moves at a relatively high speed and thus poses moderate to very low of flooding.

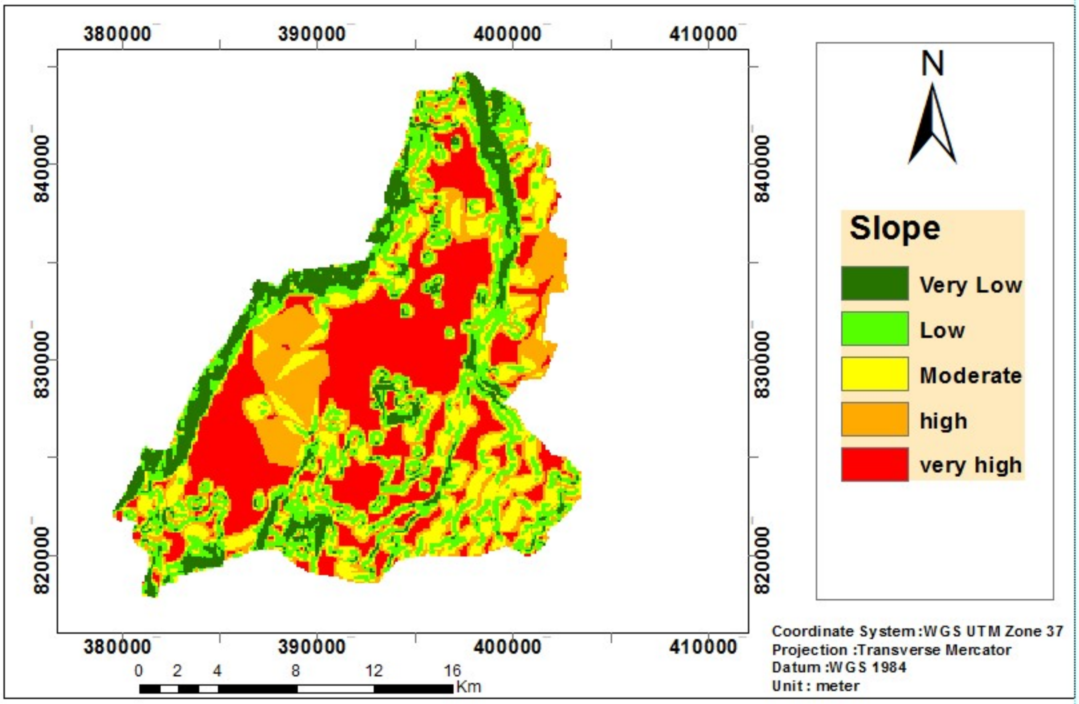

Figure 4:Slope Angles and Flood Vulnerability

Table 9: Area under each Slope Category

Vulnerability level	Slope%	Area(km ^{2})	Relative area %
Very low	16 -30	10.74	3%
Low	8 - 16	32.23	9%
Moderate	4 -8	71.62	20 %
High	2 -4	64.46	18%
Very High	0 -2	179.05	50 %
Total		358.1	100%

3.1.2. Elevation and Flood vulnerability

The reclassified elevation map covering 36.17 km 2, 51.21 km 2, 132.8 km2, 119.96 km2, and 17.90 km 2 were mapped as areas of very low, low, moderate ,high and very high Flood vulnerability level, respectively. From this (5 %) and (33.5%) of the study area were found in very high and high flood prone area respectively. The remaining parts 61.5 % of the study area were found from moderately to very low Flood vulnerable area based on elevation.

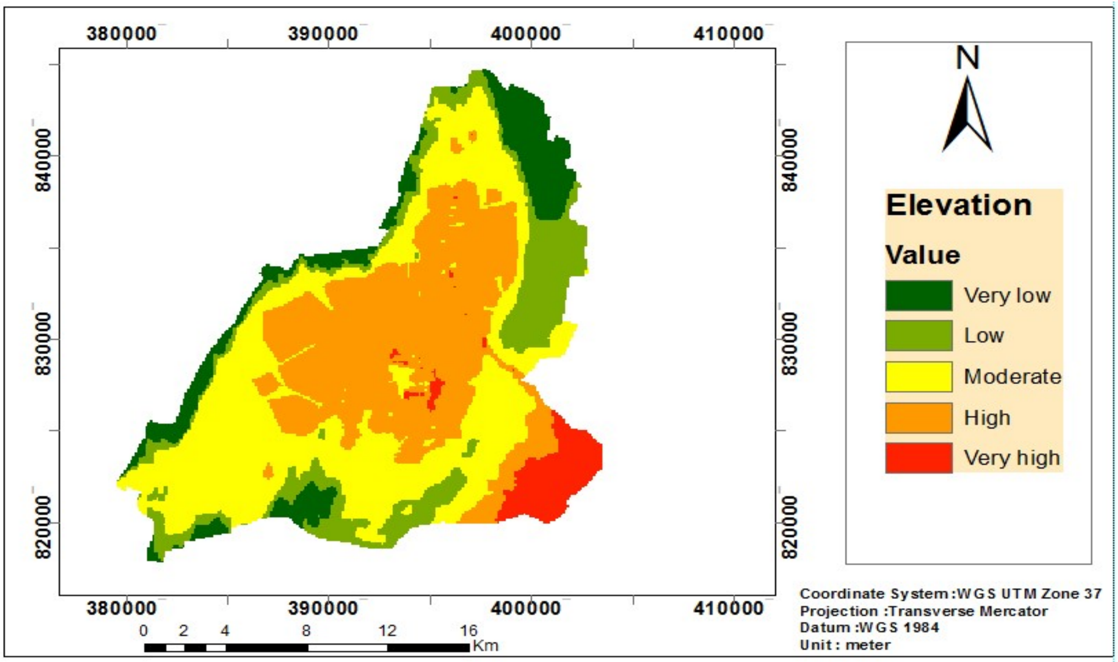

Figure 5:Elevation and flood vulnerability

Table 10: Area under Each Elevation Category

Vulnerability level	Elevation (Meter)	Area (km ^{2})	Relative area %
Very low	2196 -2040.5	36.17	10.1%
Low	2040,4 -1961.9	51.21	14.3 %
Moderate	1961.8 -1909.5	132.85	37.1 %
High	1909.4-1866.9	119.96	33.5 %
Very High	1866.8 -1780	17.91	5%
Total		358.1	100%

3.1.3. Rainfall and Flood Vulnerability

Flood vulnerability assessment requires rainfall intensity data; it is combination of precipitation characteristics (example: the amount of rainfall, intensity, duration, and spatial distribution) influences the flood events (Andi et al, 2017) .The interpolated rain fall from four meteorological station reclassified in to five classes ,then the reclassified rainfall map showed that from the total area, (9%) and (16 %) area were categorized under very high and high vulnerable area of flooding respectively depending on amount of rainfall. The following figure shows rainfall based on Flood vulnerability level of the study area.

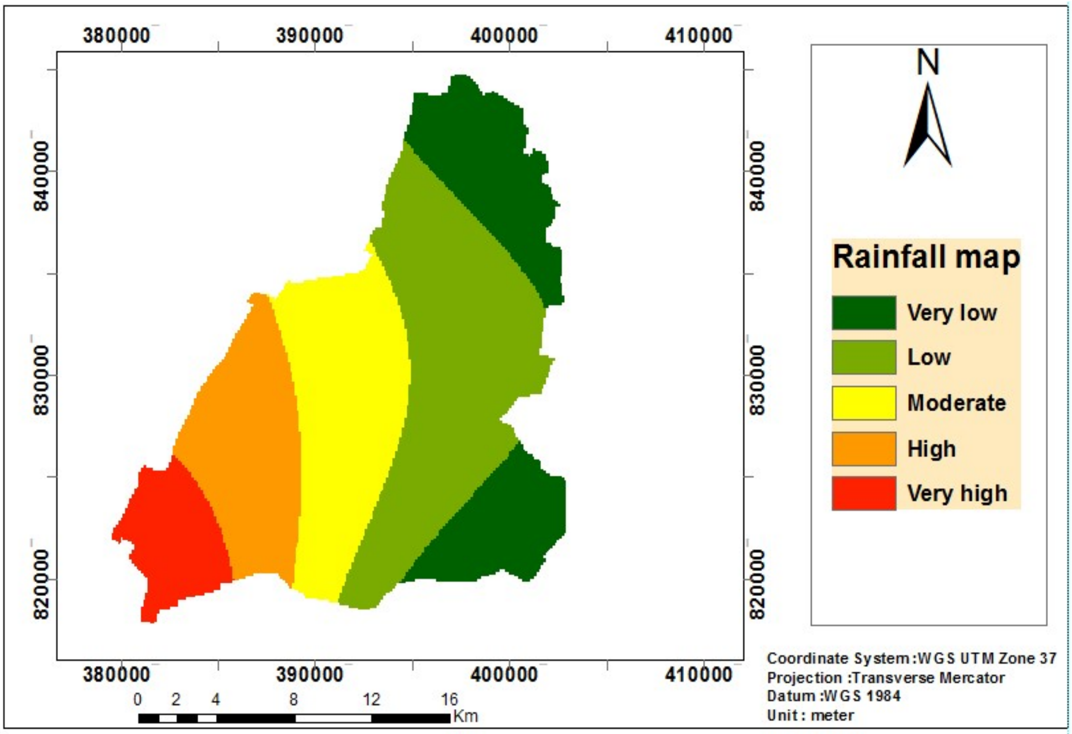

Figure 6: Rainfall Factor map and Flood Vulnerability

Table 11: Area under each rainfall amount

Vulnerability level	Rain fall (mm)	Area(km ^{2})	Relative area %
Very low	1096.4 -1135.1	71.62	20 %
Low	1135.2 -1166.8	118.17	33%
Moderate	1166.9 -1202	78.78	22 %
High	1202.1 -1244.2	57.29	16 %
Very High	1244.3 -1320.7	32.23	9 %
Total		358.1	100 %

3.1.4. Drainage Density and Flood vulnerability

Drainage density influences the water output and sediment from the system (Gregory et al.,1968) Low drainage density area is commonly found in high permeable soil ; high drainage density area is commonly found in the impermeable surface material (e.g., rocky hill slopes), arid area and areas with sparse vegetation cover (Pallard,2009). Integration of drainage density and rainfall were considered by many researchers as a parameter of flooding (Ogden et al., 2011). Areas with high drainage density are highly susceptible to erosion and result to massive sedimentation on the lower grounds. The study area is characterized with different drainage density. Density analysis established that the main drainage system of the area comprises of River Bilate (Wera) and Guder as the main rivers. Other rivers identified are Rivers Shorime, Metenchose, and Gurache are intermittent rivers with low densities. The area is also characterized with seasonal rivers which also get inundated during rainfall events. Analysis of drainage density in the area indicated that the density ranged between 0 and 3.8 .most of the rivers area characterized by low density especially at the mouth of lake Boyo, due to their Channels are closed by deposition of sediments as a result of high soil erosion during rainy season. Therefore they unable to reach the outlet water body, they caused flood on settlements round Boyo Lake. From total area 4% and 13.5% of the study area were found in very high and high flood prone area.

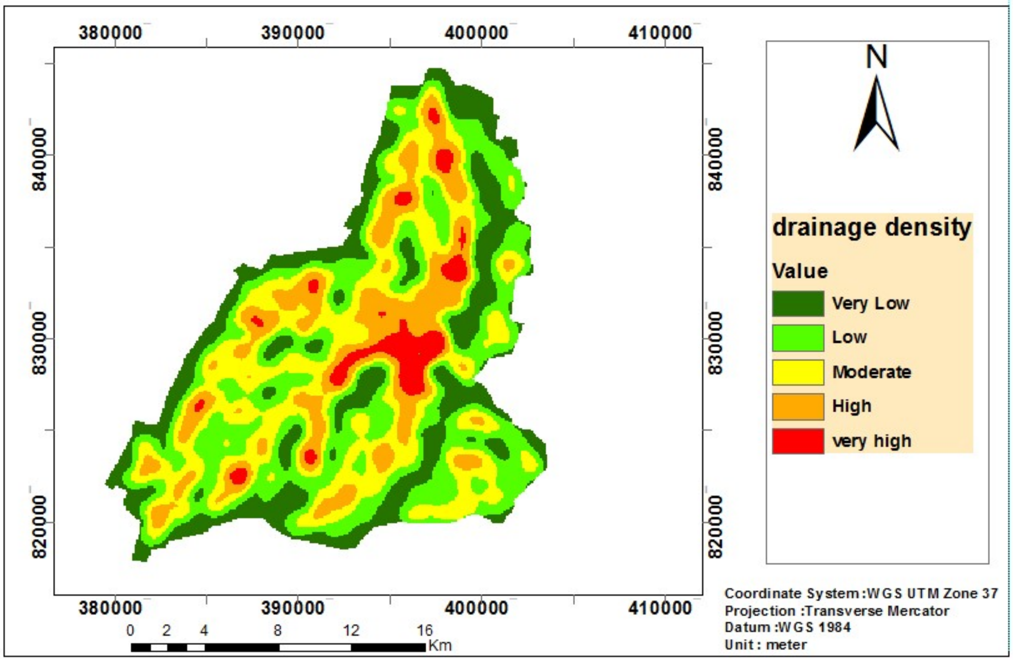

Figure.7 :Drainage Density and Flood vulnerability

Table 12: Area under each drainage density level

Vulnerability level	Drainage density (m/m^2)	Area(km^2)	Relative area %
Very Low	0 -0.7	71.62	20
Low	0.7 -1.4	114.59	32
Moderate	1.4 -2.1	109.22	30.5
High	2.1- 2.8	48.34	13.5
Very High	2.8 -3.5	14.33	4
Total		358.1	100 %

3.1.5. Land use and Flood Vulnerability

Figure .8 showed land use land cover based on flood vulnerability level. From the total area, 358.1 km2, 88.52 km2 (25 %), and 184.19 (51 %) km2 areas were leveled as very high and high vulnerable to Flood incidence, based on the susceptibility of land use land cover types for flooding. The area with moderate to very low susceptible to flood covered the rest (24 %) of the study area.

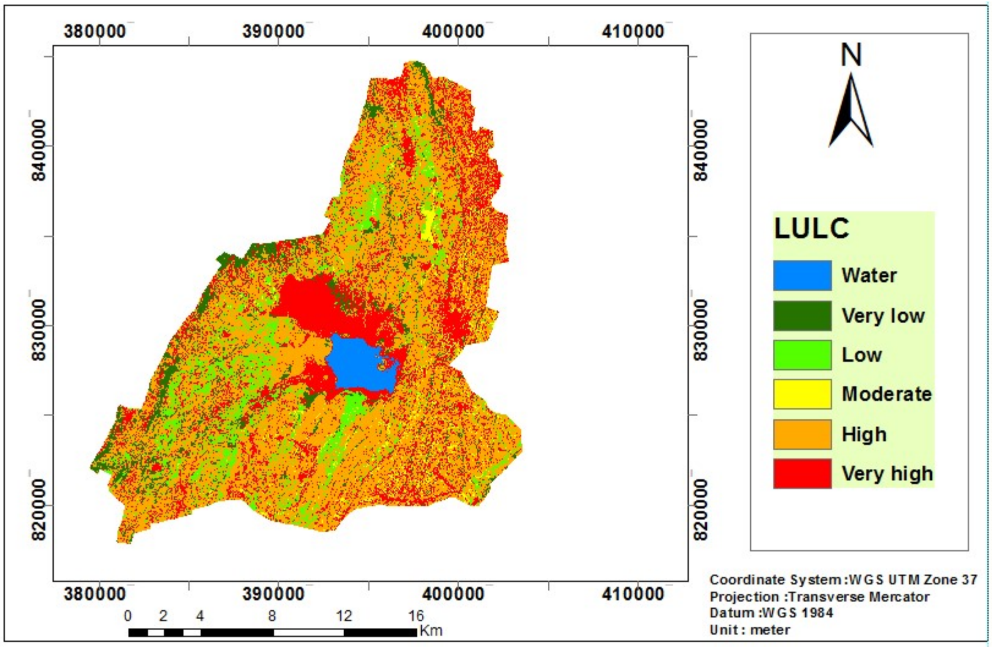

Figure 8:Land use and Flood Vulnerability

Table 13: Area under each land use category and Flood vulnerability level

Vulnerability level	Land use	Area(km^2)	Relative area %
Very low	Vegetation(1)	26.9456	8 %
Low	Grass land(2)	39.6027	11 %
Moderate	Bare land(3)	10.3788	3 %
High	Crop land (4)	184.1921	51 %
Very High	settlement and Marshy land(5)	88.5139	25%
Total		349.63331	98%

Reclassified Land use type and Flood vulnerability level of Shashogo district

Accuracy assessment

	Ground truth (Reference 2018 %)								
classified	W	M	G	V	CL	ST	BL	Total	UA (100%)
water	36	4	0	0	0	0	0	40	90
Marsh land	4	36	0	4	0	0	0	44	81.8
Grass	0	0	28	4	8	0	0	40	70
vegetation	0	0	12	28	0	0	0	40	70
Crop Land	0	0	0	0	32	0	4	36	88.8
settlement	0	0	0	4	0	36	4	44	81.8
Bare land	0	0	0	0	0	4	32	36	88.8
Total	40	40	40	40	40	40	40	280	
PA (100%)	90	90	70	70	80	90	80		OA=81.43%
omission	10	10	30	30	20	10	20		K = 0.78

Note that: W=Water body, M=Marsh land, G = Grass land, VG = Vegetation, ST= Settlement Area BL= Bare land, CL=Crop land, UA=User Accuracy and PA=Producer Accuracy

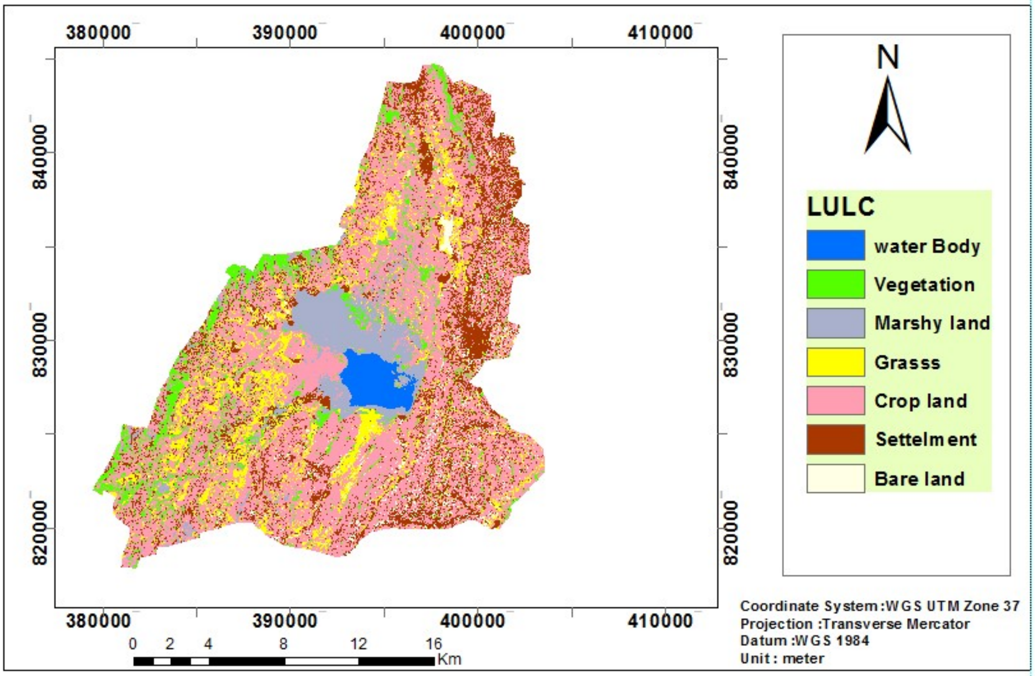

Figure 9: Land use land cover map of the study area

3.1.6. Soil Type and Flood Vulnerability

The reclassified soil map in figure 4.10 showed that, from the total area of 358.1km 2, 39.57 km2 (11.05 %) area mapped under very high, and 277.062 km2 (77.37 %) area are under high, vulnerability of flood. The reclassification was based on water retention capacity of soils, which determines Flooding. ChromicVertisols and Vitric Andosols those are poorly drained soils leveled as very high and high level of flood vulnerability respectively.

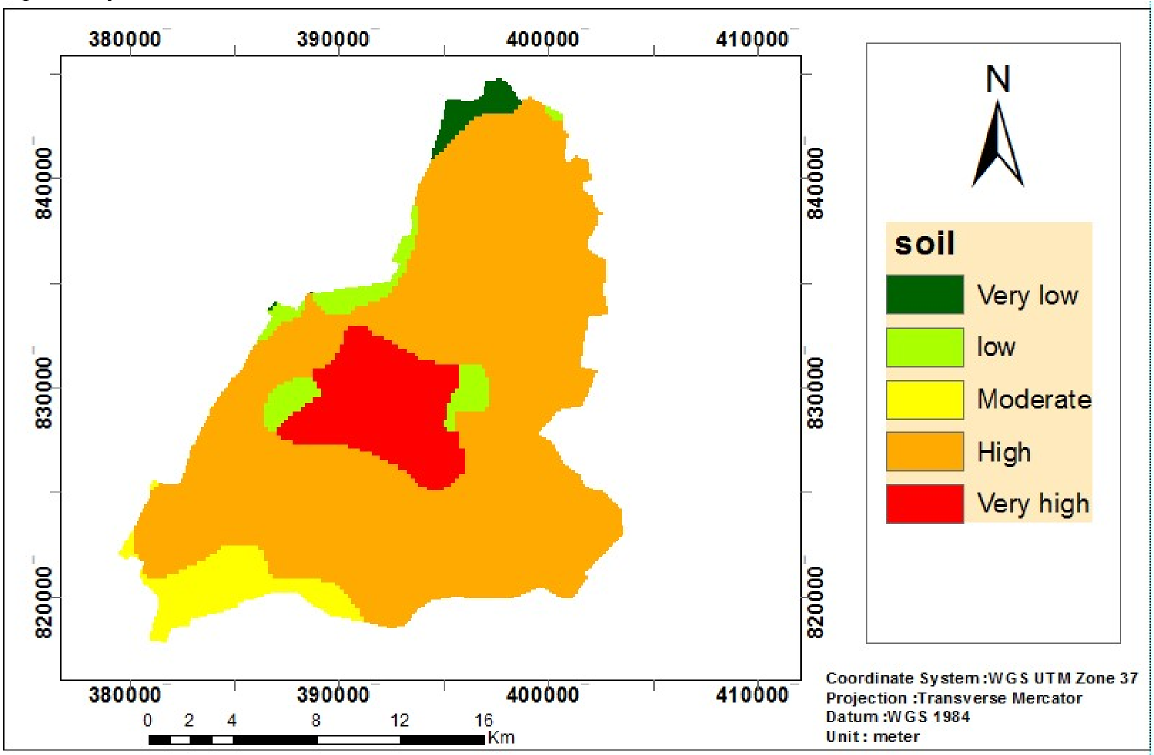

Figure 10: Soil Type and Flood Vulnerability

Table 14: Area under each soil type and Flood vulnerability level

Vulnerability level	Land use	Area(km^2)	Relative area %
Very low	Solonchack/leptosoil (1)	5.62	1.57 %
Low	Sand mixture/nosoiol(2)	15.25	4.26 %
Moderate	PellicVertisols (3)	20.59	5.75%
High	Vitric andosol(4)	277.06	77.37 %
Very high	Chromic Vertisols (5)	39.57	11.05%
Total area		358.1	100%

3.1.7. Distance to the rivers and Flood Vulnerability

Different areas in district fall under different distance categories from the river. 25.78 km^2 (7.2 %) the area falls within <200 m, which was ranked "very high" flood vulnerable area and 32.94 km^2 (9.2 %) located distance between201 -400 m in the high flood prone area. The rest (83.6 %) of the study areas were located at the distance range between 600 m -800 m and above which are considered as moderate to very low vulnerable to flooding .

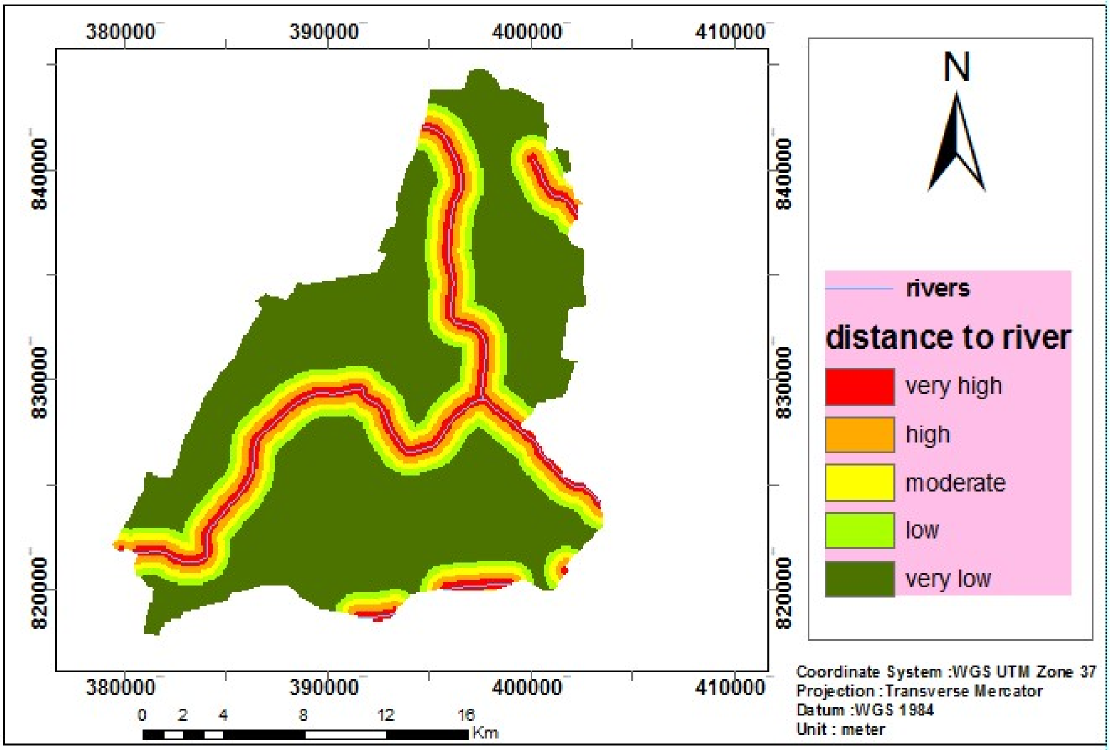

Figure 11: Distance to the rivers and Flood Vulnerability

Table 14: Area under each distance Category

Vulnerability level	Distance (D)m	Area(km^2)	Relative area %
Very high	<200 m	25.78	7.2%
high	201 -400	32.94	9.2%
Moderate	201 -600	31.51	8.8%
low	601 -800	31.87	8.9%
Very low	>801	235.98	65.9%
Total		358.1	100%

3.2. Mapping Flood areas

In this stage, the AHP results were integrated into a GIS system to map the flood vulnerable areas using Weighted Linear Combination (WLC). The WLC / simple additive weighting rely on the concept of a weighted average where continuous criterions are standardized to a collective numeric range, and then combined by means of a weighted average (Drobne and Lisec, 2009). The WLC technique can be carried out using any type of GIS system possessing the overlay. The output of this WLC method gave a map the most potential flood susceptible areas. To compute the vulnerable area, a weight linear combination was applied as shown in Equation (7).

VulnerabilityIndex=(0.21×Slope)+(0.18xdrainagedensity)+(0.15xproximitytotheriver)+(0.13×Lulc)+(0.12×Rainfall)+(0.11×Elevation)+(0.1×Soi…………………………(Equation 7)

The Vulnerability of the studied area is divided in to five classes. Those were, very high vulnerable, high vulnerable, moderately vulnerable, low vulnerable and very low vulnerable. The output was a flood vulnerability map with five vulnerable areas (Figure: 12). The study area is dominated by high flood vulnerability which covers 47.98% of the study area. The very high and the high vulnerable zones are concentrated in the Central part of the study area and very low vulnerable area a found at upper parts of the study area specifically in the Northern and North West part. Moderately vulnerable areas are the major agricultural area and included settlements as classified in the land use map. Most of the areas of agricultural and the grasslands fall within moderate Flood vulnerable areas. The flood vulnerability map depicts the area susceptibility of an area to flooding.

As can be seen in Table: 15, means more than 47.9% of the area was found in high flood prone area and the remaining as moderately vulnerable to very low vulnerable to flood and flood related problems. The Very High vulnerable areas have a total coverage of 1.01km 2of the total area. "High" vulnerable areas have total area of the district covers 171.82 km2,the "Moderately" vulnerable areas are, covers 151.73 km2 of the total area , "low" vulnerable area covers 32.16 km2and very low vulnerable area covers 1.33 km2(see table 4.13).

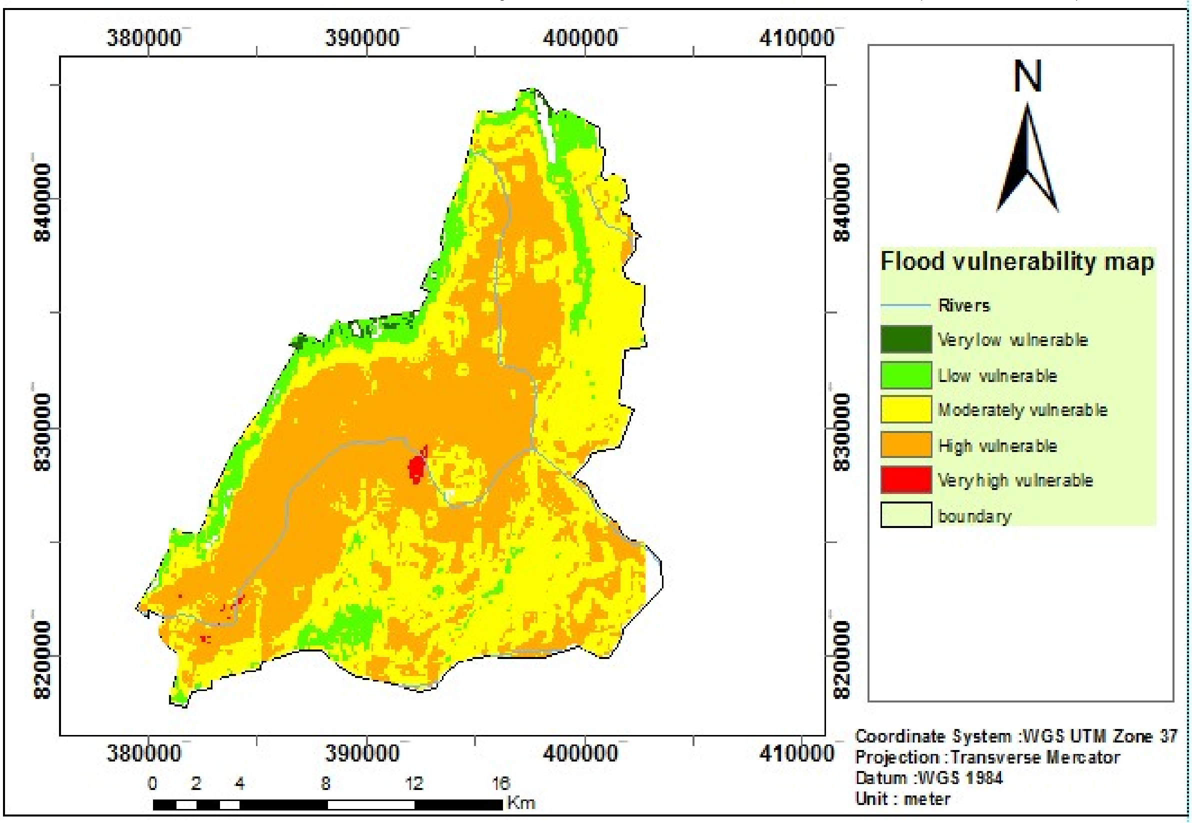

Figure 12: Flood vulnerable area map of Shashogo District

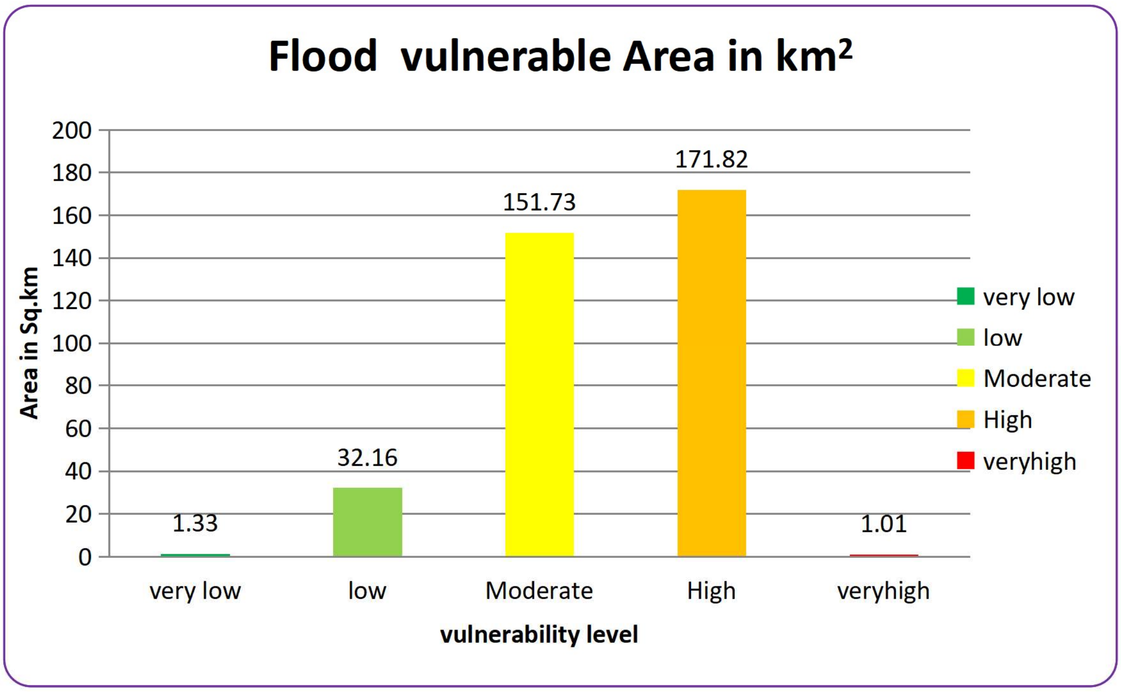

Figure 13: Flood vulnerability area chart

4. Conclusions and Recommendation

This study tried to assess the area susceptible to the impact of flood hazard, using integrated approaches of GIS, Remote Sensing, and spatial multi-criteria evaluation through the Analytical Hierarchy Process (AHP). The factors such as slope distance to rivers, elevation, rainfall, soil type, drainage density, and land use / cover were applied to predict affected area of flooding. The AHP calculation showed that slope has the highest weight in determining vulnerability to flooding through the spatial-weighted overlay. The slope parameter was the most important parameter because the slope influences the flow direction, runoff and soil infiltration.

The study mapped out flood vulnerable areas in five different classes namely, very high, high, moderate, low and very low. Result showed that 1.01 km2 (0.28%) of the entire study area was very high vulnerable, 171.82 km2 (47.98%) highly vulnerable, 151.73 km2 (42.37 %) are moderately vulnerable, 32.16 km2 (8.98%) are low and 1.33 km2 (0.37 %) very low vulnerable area for flooding. The study critically examined the role of GIS in decision-making and also outlined the evaluation approach for many criteria in decision process. The flood vulnerability map produced can assist planners, policy makers and emergency service providers as a valuable tool for assessing flood risk areas. Flood vulnerability can be reduced by adoption of non-structural measures, which include early warning, the development of land use planning, and relocating settlements from high flood vulnerable area or byprotecting development in those risk areas the same result can be obtained as relocating. Creating awareness to residents who live in high flood vulnerable area would help when evacuation plan implemented during flooding. The structural measure is the second method of flood mitigation measures but it is at the beginning step not fully implemented on all flood prone area due to financial constraints. This study confirms that GIS and Remote sensing techniques provide more integrated approach than Hydrological modeling. Using GIS and Remote sensing have advantages. Flood vulnerability assessment and modeling are complex issues that require an integrated approach it need combining more data's. This makes Geographic Information Systems (GIS) and Remote Sensing, multi-criteria analysis powerful techniques for the understanding of floods than Hydrological modeling. Creating flood vulnerability maps to provide basic information plans and communicate to decision makers and the public for the effective management of these Flood risks. The strength of using GIS and Remote Sensing for flood vulnerability assessment and modeling is not only to generate a visualize map of flooding, but also to create the potential to further analyses and understand the process which results in this event. Satellite images were shown to be very important for current Land use/ cove mapping.

The Multicriteria analysis methods provides a framework which can handle different views on the identification of the elements of a complex decision problem, organize the elements into a hierarchical structure, and study the relationships among components of the problem. The use of Analytic Hierarchy Process (AHP) developed by Saaty (1980) is one of the best known and most widely used MCA approaches. Therefore, it has been shown that AHP GIS based model combination has potentiality to provide non-biased approach in making decisions in disaster studies. Some limitations were, the study only considered seven factors such as, slope, distance to the river, elevation, rainfall, land use, soil and drainage density from the study area , it is better to use more datas like daily rainfall intensity , or runoff to find more accurate result. In addition to these to calculate flood frequency and probability, using river flow data from gauge station are more important than rainfall data, to know contribution of upstream watersheds and catchment to consequent flooding of the area. Therefore for future other researcher needs to consider these and add these data to find better results.

Recommendations

This finding provides information on flood vulnerability level that could be used by the decision makers to act upon the current land use policy for reducing vulnerability in Shashogo. Thus the responsible bodies of the district as well as the Region should incorporate the flood vulnerability assessment studies in their development strategies. So in order to mitigate vulnerability in Shashogo the following measures are recommended;

- Forestations and reforestation of high lands, and Watershed management practices in upper catchment is vital in reducing future flood disasters in Shashogo district.
- Construction of flood protection structure and Soil water conservation measures in degraded area of watershed are important to decrease flood and to reduce sediment transportation by erosion.
- Non-structural flood management technique such as flood vulnerability maps should be adopted integrated with structural measures, Opening artificial channels to facilitate discharges to lake, construction of dike to increase rivers density and avoiding artificial drains which break natural flow of the streams are necessary.
- Avoiding further development proximities of more vulnerable areas should be done by the concerned body to prevent more significant damages.
- An effective early warning and forecasting system should be supported by meteorological information, is important and it needs to be established at regional level.
- Researchers can use this study as a base and recommended to carry out further research work by using additional data to reduce flood extents, by implementing appropriate flood management technique.

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