ASSESSMENT OF FLOOD VULNERABILTY AREAS IN BILLIRI LOCAL GOVERNMENT AREA OF GOMBE STATE, NIGERIA.

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Abstract

There is a significant increase in the occurrence of floods globally, with an impact on habitation and different sectors of the economy. This, in turn, necessitates the use of different flood mitigation strategies, wherein flood vulnerability assessment plays a significant role. The research assessed the overall flood vulnerable areas in Billiri local government area of Gombe State, Nigeria. The factors considered include; slope, elevation, rainfall, soil, drainage, land use and land cover factor. The coordinate of the study areas was obtained using global positioning system (GPS), flood risk factor was analyzed, classified and integrated/overlay to produce final flood prone map of the study area using weighted overlay methods in ArcGIS. According to flood risk factors analysis, the results indicates that southwestern part of the study area is more vulnerable to flood, which include villages such as Ayaba, Shela, Tudu, Kwaya, Lakarai, Sansani, Latoddo, Polido and Fagla respectively. Based on the flood risk factors, slope contributed highest percentage 15.40%, elevation 8.80%, rainfall 3.10%, land use and land cover 10.80%, drainage density 5.90% and soil factor having 1.90%. Based on their hazard level classification, slope factor happens to be the number one factor of flood disaster in the area. Generally, the result of the integrated flood vulnerability map showed 34.41% of the study area is highly vulnerable to flood. The flood mitigation measures required based on the research was creation of dams to control flood, proper channelization, use of flood warning system. Floodplain restoration, public awareness, and suitable drainage system.

Key words: Remote sensing, Flood Vulnerabilty, Overlay, Billiri, GPS.

Introduction

Floods are one of the most devastating and costly hazards worldwide, its contribution can be attributed to factors like climate change impacts on the hydrologic cycle, land-use changes and increased density of habitation activities in flood-prone areas (Deepak *et al.,* 2020). a condition of flood exists when the discharge of a river cannot be accommodated within the margins of its normal channel, thus water spreads over adjoining low-lying grounds on which Farmlands or urban structures including residential areas may occupy (Abashiya *et al.,* 2019). Floods are a leading natural disaster, common and costly, and responsible for about one-third of natural catastrophes. Losses caused by floods have been rising rapidly because of extreme weather conditions, urbanization, and inadequate disaster response. Hydrologic model–based flood forecasting systems have been regarded as the most effective way for flood early warning and monitoring and subsequent hazard mitigation and management (Huan *et al*., 2012). Flood is overflow water that submerged land that is usually dries (Huan *et al.,* 2012). Flood is an expanse accumulation of water which exceeds the carried capacity of the existing channel. The GIS tool plays a vital component of flood risk assessment due to the evaluation Process that needs spatial information. The practice of a standard approach for evaluation and merging distinctive data affect the precision and comparability of assessment outcomes. Some nations have established national guidelines to assess flood risk potential, In Addition, GIS can be utilized to study international, regional, and local flood risks and Guide the implementation of a risk mitigation plan (Jerome *et al.,* 2022). Globally flood can be devastating and they frequently compared to all natural disasters, because they have number of casualties and economic losses, one third of the global natural disaster can be considered to be flood (Jerome *et al.*, 2022).

In Africa, flood occurs in most part of the continent as in Rwanda, Kenya Somalia, Nigeria, Burundi etc., The worst flood occurrence in this areas was in 2020 accounting for 700,000 people are affected as result of excessive rainfall leading to massive flooding and landslide, causing 430 deaths, notably in Kenya and Rwanda. Africa is located in the tropical zone which is accompanied by the tropical climate (Jerome *et al.*, 2022). Nigeria, experience the worst flooding which account for the total losses of properties worth 16.9billion dollars in 2012. The prevalence of flooding within Nigeria which has been generally attributed to climate change and poor urban planning is an issue of critical importance within the context of national development. Over the period 1985 to 2014, flooding in Nigeria has affected more than 11 million lives with a total of 1100 deaths and property damage exceeding US$17 billion. Although more frequent floods are recorded in Niger, Adamawa, Oyo, Kano and Jigawa states possibly due to the influence of rivers Niger, Benue, Ogun and Hadeja, Lagos state seems to have experienced most of the floods in the country. With rapid population growth and urbanization in the country the risk of flooding to human lives and properties assumes critical dimensions. In Gombe state urban flooding occur as a result of poor constructed drainage system which result to frequent flooding (Abashiya, *e*t *al.*, 2019), the pattern of the place plays an important role in accessing hydrological conditions and hence enhances the understanding of the urban flood assessment, The drainage pattern of a place plays a major role in assessing hydrological conditions and hence enhances the understanding of urban flood assessment,. Flood can be as a result of upslope factors, coincidence, flood also occur as result of high precipitation intensity in which the rate of run off Increase as the rate infiltration is reduced, global warming causes flooding through ice melt, when there is rise in temperature and sea water volume is increased, flood have both negatives and positive impacts, direct and indirect effect on environment and people, poor drainage system is the most prevailing cause of flood in urban centers. The major challenge in multi-criteria evaluation (MCE) is determining how to combine information from multiple criteria to generate a single index of assessment, to aid in the processing, data integration and operation of geographical Information system (GIS) software. Management of flood is an obtuse, complex phenomenon that should be periodically revised roughly 30-50 years (Tariq, 2020). The appropriate flood warning systems developed in the developing countries is the short message service (SMS) to directly warn in remote flood areas where mobile phone network are available and there is high level of mobile phone penetration (Goodwin, 2012).

The National Emergency Management Agency, NEMA (2013) reported that about 7.7 million people in Nigeria had been affected by flooding between the period July to October, 2012 when 363 were killed and 18,282 injured. The devastating flood event occurred due to heavy downpours in many parts of the country. The flood of August, 2012 along River Niger and Benue that submerged most parts of Lokoja town blocked the major road linking the Northern and Southeastern part of the country. Also the released water from Lagdo Dam in the Cameroun Republic affected parts of Adamawa State in Nigeria (Abashiya et al., 2019). In Gombe state urban flooding occur as a result of poor constructed drainage system which result to frequent flooding (Abashiya *et,al* 2016),the pattern of the place plays an important role in accessing hydrological conditions and hence enhances the understanding of the urban flood assessment (Abashiya *et,al* 2016). In Gombe flooding occur in Kwami, Akko, Yamaltu Deba, Funakaye and Billiri Local Government Areas,

its impacts are critical issues, With history of devastating floods which affected million populations and caused fiscal losses amounting to billions of US dollars, the importance of exploring more realistic human which account to the loss of lives and properties. In Gombe state most floods occur as result of heavy rainfall and accompanied by poor drainage systems (Abashiya *et al.*, 2016).

In recent times flood rendered many houses inhabitant, farmland un-productive and destruction of human and animal life. Flooding, is one of the most frequent and widespread of all environmental hazards and of various types and magnitudes, occur in most terrestrial portions of the globe, causing huge annual losses in terms of damage and disruption to economic livelihoods, businesses, infrastructure, services and public health. Long term data on natural disasters suggest that floods and wind storms have been by far the most common causes of natural disaster worldwide over the past 100 years, (Dabara *et al*., 2012). The effect of flooding have led to deplorable conditions of living of people in the study area which force people either to evacuate or to abandoned some houses completely, farming is no longer encouraged and commuters are faced with difficulties in transportation in transport routes. Based on recent investigation, the research conducted in the study area was of soil fertility and land use. (it is in this view of this problem that this research seek to examine the flood prone areas in Billiri local government of Gombe state and bring out the possible solution for future sustainability).

In Gombe state urban flooding occur as a result of poor constructed drainage system which result to frequent flooding (Abashiya *et,al* 2016),the pattern of the place plays an important role in accessing hydrological conditions and hence enhances the understanding of the urban flood assessment (Abashiya *et,al* 2016). In Gombe flooding occur in Kwami, Akko, Yamaltu Deba, Funakaye and Billiri local government, which account to the loss of lives and properties. In Gombe state most floods occur as result of heavy rainfall and accompanied by poor drainage systems (Abashiya *et al.,* 2016).

Flood occurrence in the study area rendered many people homeless and farmland unproductive, therefore Result to obtain during the study will be of important on how to prevent and control flooding in the study area, Findings of this research will also be of importance use at all times to students in geography agriculture and town planning.

The study result will, highlight on what way and manner a community can be managed and exhibit proper flood management. The aim of the study is to assess the flood prone areas in Billiri local government area., trough the following specific Objectives

1: To examine the flood risk factors in the study area.

2: To determine the flood vulnerable areas in study area.

3: To map the flood prone areas in the study area

2.0 MATERIALS AND METHODS

2.1 Study Area

The study area is Billiri local government gombe state, the area lies between Latitudes 9°51'40"N, 9°54'46"N and Longitudes 11°12'2"E, 11°15'00"E, in north-eastern region of Nigeria, and it covers an area of about 30 km2 (ministry of land survey), in southern part of gombe state. Billiri local government shares boarder Kaltungo from east, Shongom from south and Akko from north and west respectively.

Billiri lies in the northern guinea savanna of Nigeria, with an average rainfall of about 897mm, main daily temperatures range from 28 to 32°C (GSADP, 2015). The area is tropical continental (Sudan) climate. The climate consists basically of two Seasons, a rainy season and dry season. The onset of the rainy season is from April-June and ceases at the end of October, with an average rainfall of about 2.38 mm annually. This season is also characterized by humidity and temperature of about 25 0C while in the dry season, the temperature of about 32 0C is usually recorded (Abdullah, 2017).

The geologic formation of the study area is basically on the basement complex rocks, the area is underlain predominantly by basement rocks, and The Bima Sandstone forms most of the Billiri area. The topography (hills and valleys) in the study area has influence on the drainage pattern (Abdullahi, 2017). The topography (hills and valleys) in the study area has influenced the drainage pattern; The northeast and south-west structural trend which is related to the directional flow of the stream, rivers and valleys forms dendritic drainage pattern (Abdullahi, 2017).

The soil in the study area were dominantly sandy loam with fertility status of 24-84% sand, 3-47% salt and 8-32% clay in 0-15cm, (Babaji et al., 2019).

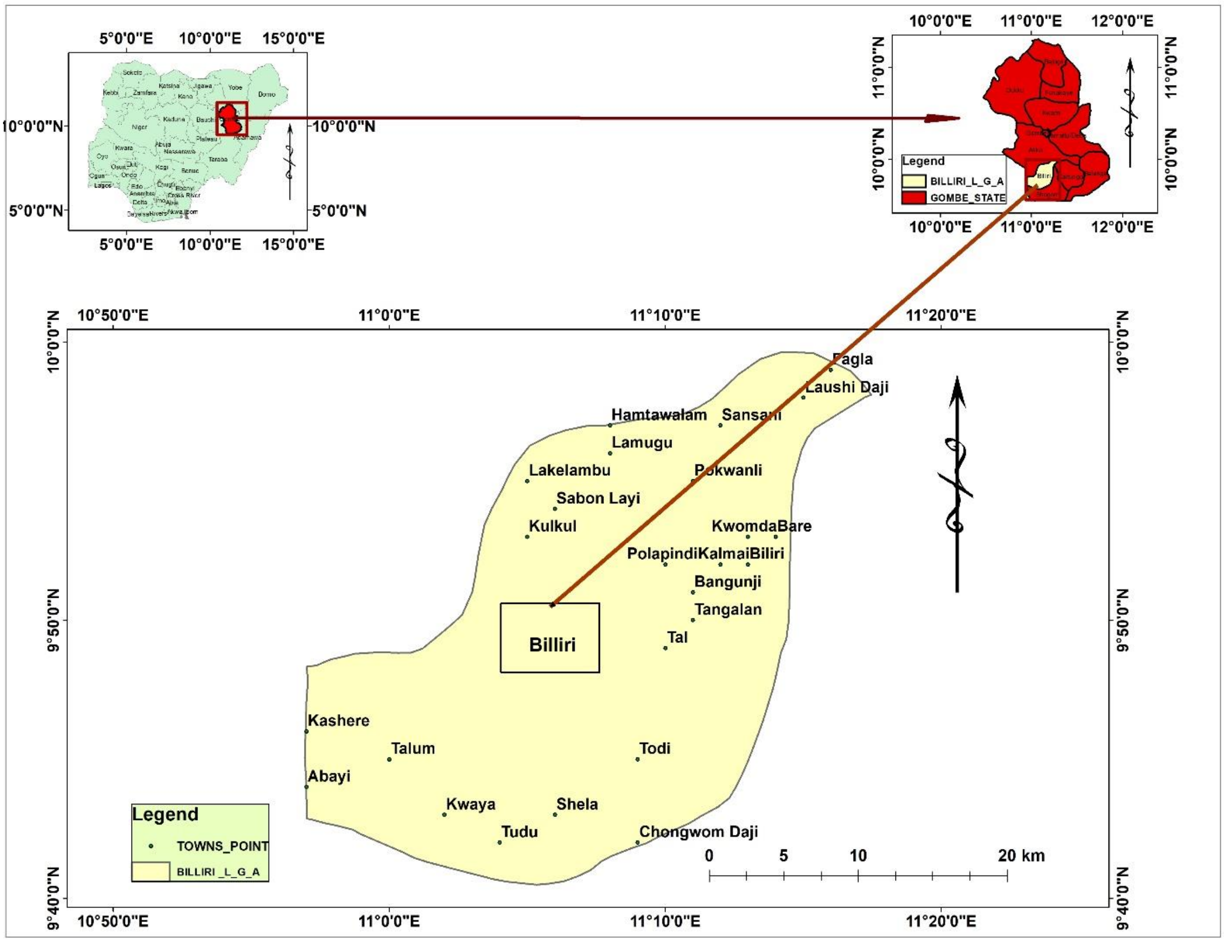


Fig 1 Billiri L.G.A showing study area.

(Source: Modified from the Administrative map Gombe, Nigeria)

2.2 Methodology

This is concern with the method of data collection, which is of two types namely; primary and secondary source of data, the primary and the main source of data by using the geographic information system (GIS), in which the coordinate of the study area will be obtain to map and analyzed, secondary data include; rain fall data from Nigerian metrological agency, journals textbooks, related works.

2.3 Field survey

This was the first step in the data collection exercise, A reconnaissance survey of the area will be undertaken and will provide opportunity for familiarization with the study area. Here the coordinate were obtained and the study area is mapped.

2.4 Data Analysis

The method of data analysis used in the this research is through the use of ArcGIS, in which the coordinate were used to map the study area and the data and the data obtained was interpreted. The major challenge in multi-criteria evaluation (MCE) is determining how to combine information from multiple criteria to generate a single index of assessment, to aid in the processing, data integration and operation of geographical Information system (GIS) software.

2.5 land use/land cover

Table 1: Land use/Land cover, class description

S/N	Class	Remark
1	**Water**	Areas where water was predominantly present throughout the year; may not cover areas with sporadic or ephemeral water;
2	**Vegetation**	Any significant clustering of tall (~15 feet or higher) dense vegetation, typically with a closed or dense canopy
3	**Built Area**	Human made structures; major road and rail networks

Source: Impact Observatory's deep learning AI land classification model Classes, **2022**

2.6 Data collection and methodology

For this study, secondary data collected from books, journals, manuals, were used. The Digital Elevation Model (DEM) and other important Parameters for flood vulnerability plotting were investigated with ArcGIS. Flood producing aspects such as drainage density, digital elevation model, land use/land cover, soil type, rainfall, and slope were designed for flood vulnerability valuation with ArcGIS.

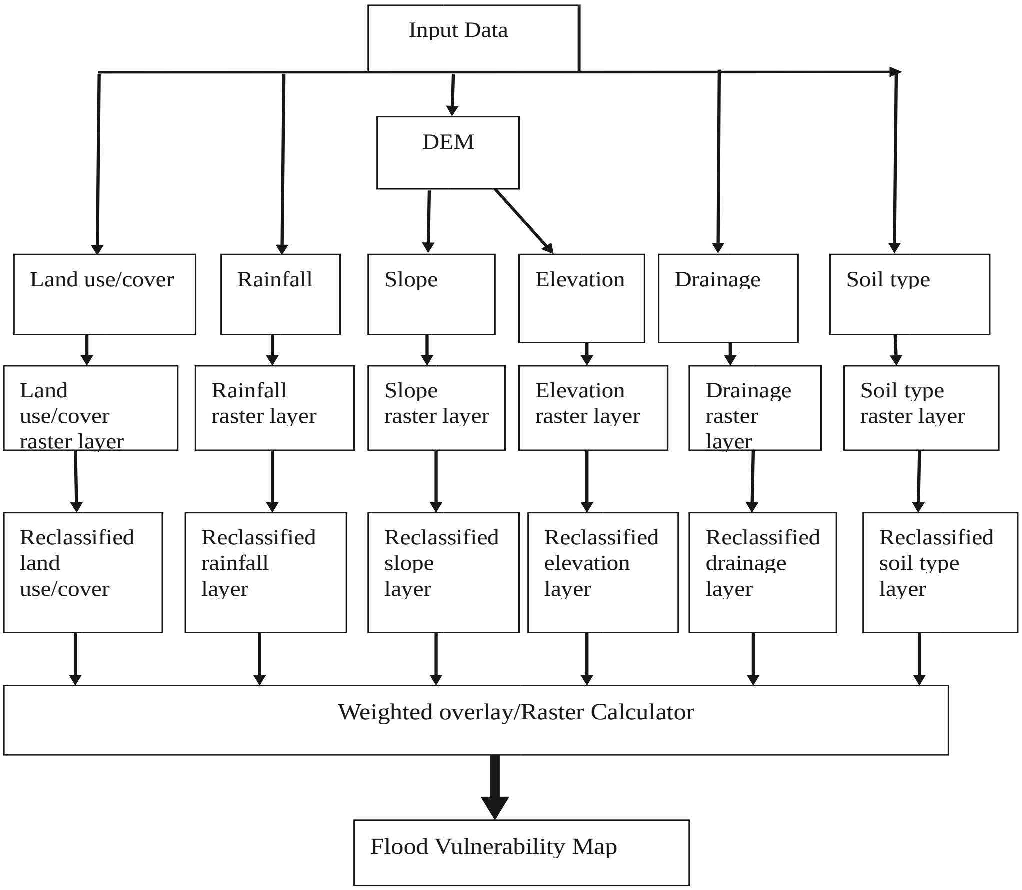


Figure 2: Methodology flow chart

For the development of a map of flood plains, 1901 to 2022 gridded rainfall/precipitation data from Climatic Research Unit(CRU) record and 30m by 30m high resolution of DEM of a watershed in raster format been collected from the USGS(United State Geological Agency were used for this study.

3.0 RESULT AND DISCUSSION

3.1 Flood risk factors

3.1.1 Slope Factor

The slope of the study area resulted from a 10-meter contour interval characteristic rank which was derived from 30m by 30m Digital Elevation Model.

As presented in Figure 3(b), the re-categorized slopes have been given significance one to five through the upper value, This categorization method segregates a variety of feature worth to the same sized sub-ranges which allow specifying the number of intervals.

Table 2: slope Hazard classification

Hazard Level	Slope(% Rise)	Rank Class	Area (km^2)	%
Very High	0 – 2.45	5	349.10	45.88
High	2.46 – 9.8	4	364.89	47.96
Moderate	9.81 – 22.05	3	30.98	4.07
Low	22.06 – 39.2	2	11.25	1.48
Very Low	39.21 Above	1	4.63	0.61

The smaller slope value was flatter topography and, likewise, the upper slope values were the steeper topography. Depending on their vulnerability to inundating, slopes were characterized into five ranks. According to these classifications, areas with the smallest slope are ranked to class five (0.61%) and are not likely to be affected by the flood. Similarly, a high vulnerability ranked to class five (45.88%), and are extremely likely to be affected by flood. The break values were checked depending on the local information, expert knowledge, as well as the achievable comprehensions for slope hazard map in figure 2

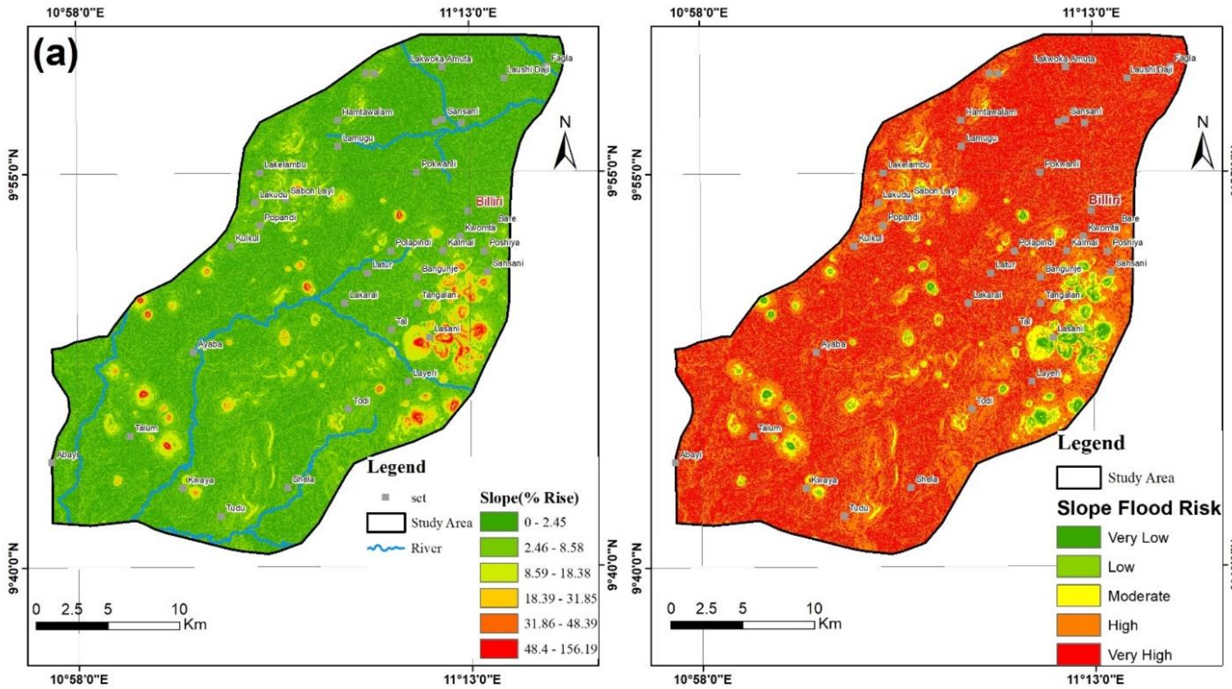


fig 3: (a) Slope distribution fig 3(b) slope hazard classification

3.1.2 Elevation factor

It is evident that the proximity or distance from river and elevation are the two major contributors of physical vulnerability (Deepak *et., al* 2020). DEMs were changed to elevation raster layers with the ArcGIS conversion tool. The elevation raster layers were then re-categorized into five subgroups using a normal classification system (Natural break). The latest value was re-categorized to flood vulnerability rating/rank. Hence, the categorization procedure to the smallest elevation was extremely affected by the flood. Thus, class five upper elevations have been affected by the flood more than class one as shown in Figure 4(b).

Table 3: Elevation hazard classification

Hazard Level	Elevation Range	Rank Class	Area (sqkm)	%
Very High	291 - 368m	5	215.22	28.25
High	369 - 423m	4	226.21	29.69
Moderate	424 - 483m	3	227.60	29.87
Low	484 - 573m	2	62.44	8.20
Very Low	574 - 900m	1	30.44	3.99

The lesser elevation worth mentioning was the flatter topography and the upper elevation was the steeper topography. Depending on their vulnerability to flooding, it has been categorized into five classes. An area at the lowest elevation was extremely affected with flood ranked to class five (<291m). Subsequent high vulnerability is ranked to class four, moderate ranked to class three , low ranked to class two and very low ranked to class one (>574m).

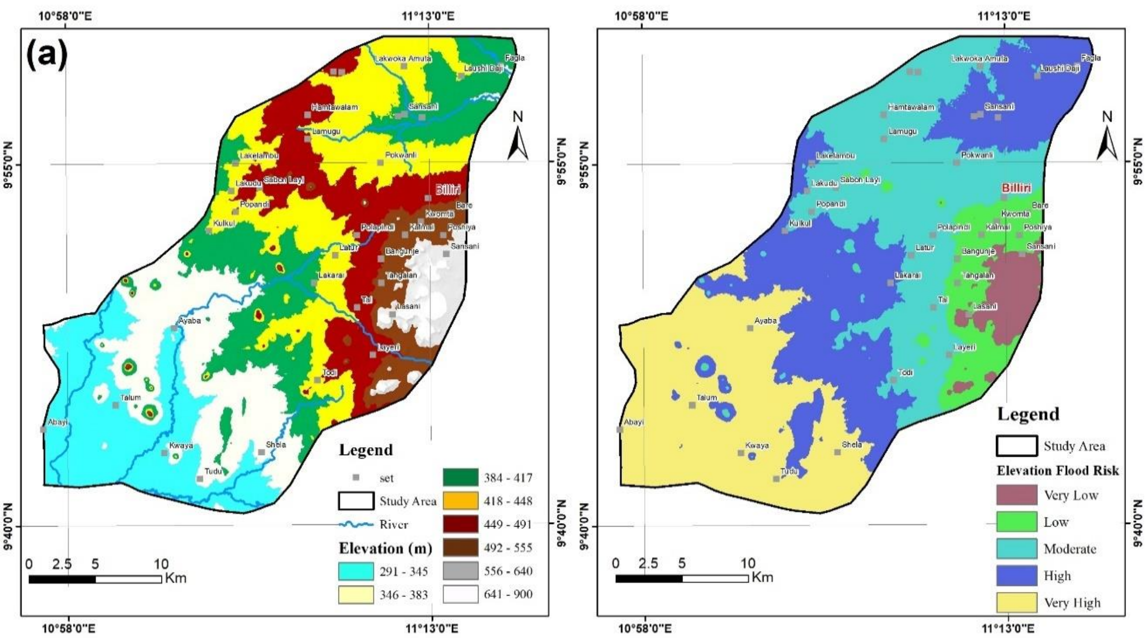


Figure 4: (a) DEM Layer and **Figure 4: (b) Reclassified Elevation Hazard**

3.1.3 Rainfall factor

This was a point from the data collected 50m gridded spatial layer. From this data, annual average rainfall was calculated for each station using Inverse Distance Weight (IDW) method and was converted to the raster layer which is ultimately re-categorized into five ranks using Natural break. The re-categorized precipitations were provided with one to five through the upper value.

Table 4: Rainfall hazard classification

Hazard Level	Rainfall Ranges/Month	Rank Class	Area (km^2)	%
Very Low	79.57–80.25 mm	1	141.6959	18.60987
Low	80.26–81.22mm	2	132.868	17.45044
Moderate	81.23–82.15mm	3	216.0211	28.3715
High	82.16–83.01mm	4	155.2265	20.38693
Very High	83.02–84.02mm	5	115.5904	15.18126

During the categorization system (as presented in Figure 5), the higher rainfall value, is extremely affected with extreme exposure to overflow and was categorized as class five (>83.02 mm/year), high ranked to class four, moderate ranked to class three, low ranked to class two and very low ranked to class one (<79.57 mm/month).

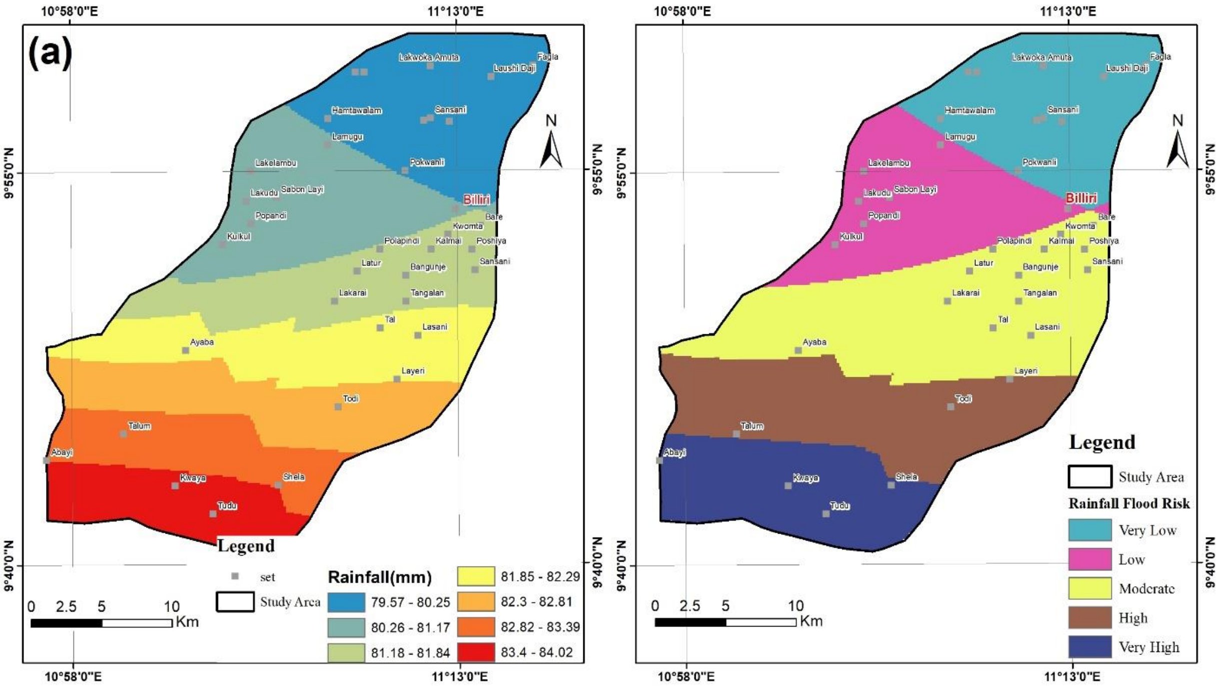


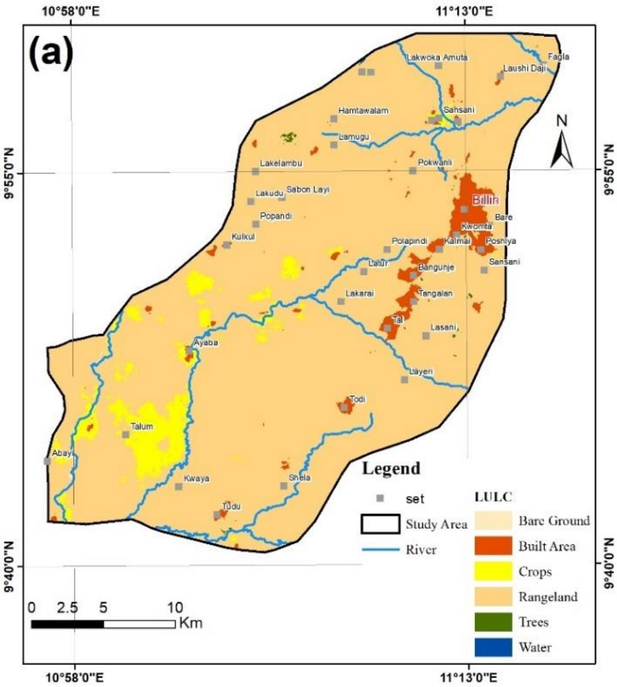
Figure 5: (a) Mean annual rainfall Map **Figure 5: (b) Rainfall Hazard Map**

3.2 Land use/Land cover Factor in Relation to flood Risk

Land use/Land cover of the watershed area was reassigned with classified land use/land cover form in five common grades and was improved into the raster layer with five classes, depending on their capacity to raise or reduce the rate of inundating. Hence, Water land use type can increase flood degree in the area and it is ranked to class five, bare land is ranked to class four, rangeland is ranked to the class three, cropland are ranked to class two and trees is very low capability to create flood and is ranked to class one.

Table 5: land cover and land use hazard classification

LULC Hazard	Rank Class	Area (km^2)	%
Very Low	1	0.06	0.01
Low	2	37.08	4.87
Moderate	3	700.60	91.91
High	4	23.90	3.14
Very High	5	0.61	0.08



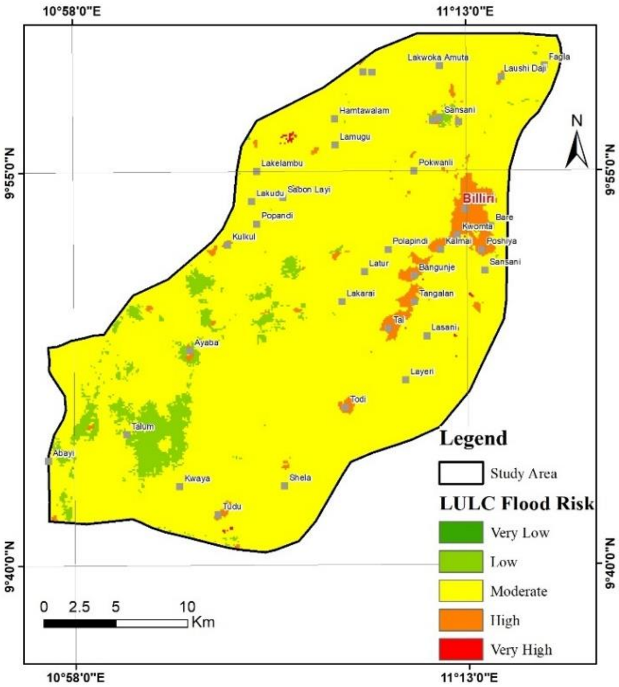


Figure 6 :(a) Land use/Land cover   Figure 6(b) Reclassified Land use/Land cover

4.3 Soil Factor

There are a variety of soil types, among these four (4) major soil classification are recognized in the study area according to the hydrologic soil grouping scheme of FAO (Food and Agricultural Organization). These are Arenosols, Lixisols, Technosols and Vertisols. Hence, it is classified into four mutual clusters and was renewed into a raster format. Further, raster layer classes were re-categorized into four as well given by the obtained soil classes, and a new value change was made based on their flood danger rating. The class that has extremely high capability to produce incredibly high flood rate were rank with class five and incredibly low capacity to produce flood rate were ranked to class one.

Table 6: Soil hazard classification

Hazard Level	Rank Class	Area (km^2)	%
Very Low	1	193.56	25.39
Low	2	112.41	14.75
Moderate	3	453.09	59.44
High	4	3.22	0.42

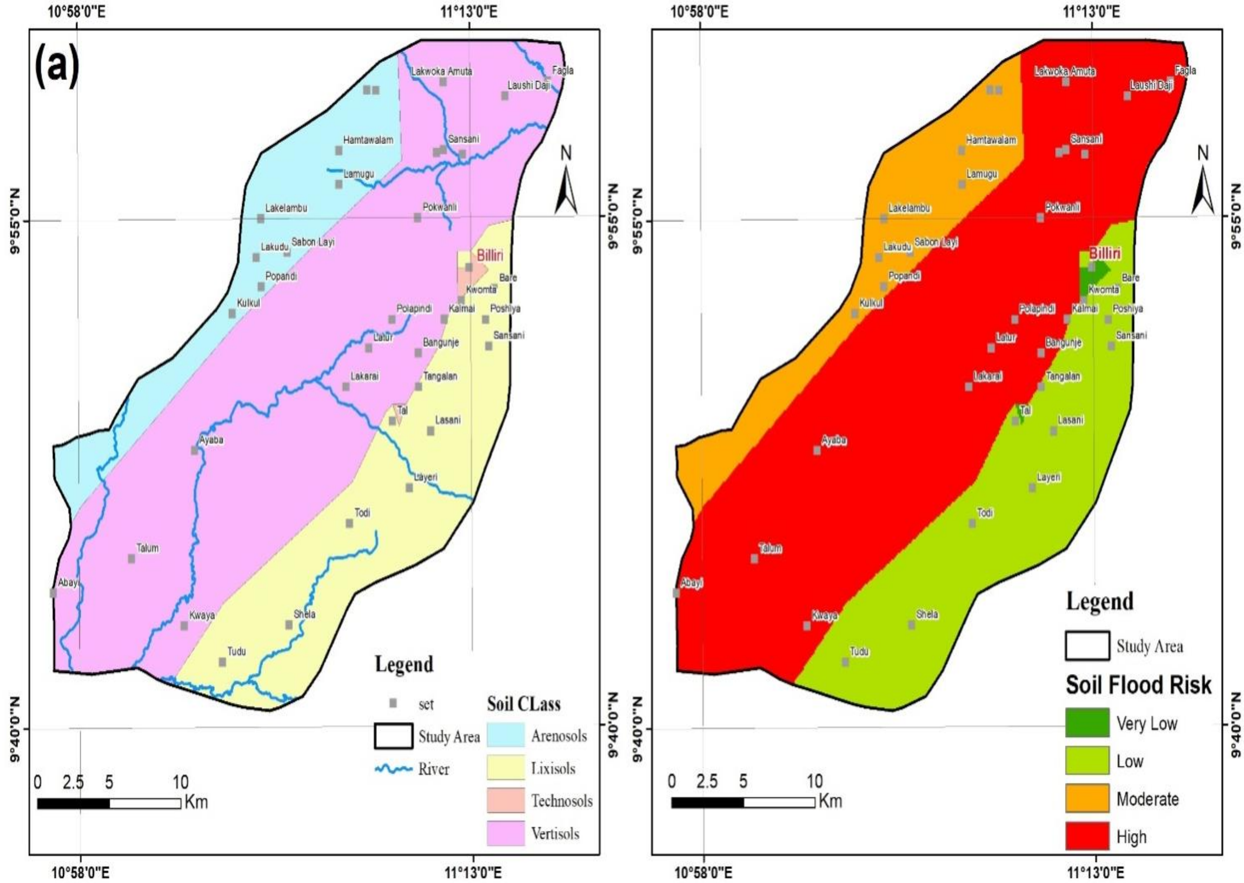


Figure 7: (a) Soil map **Figure 7 (b) Reclassified Soil Map**

4.4 Drainage Factor

The drainage density was the whole length of all the streams and rivers in drainage divided by the whole area of the drainage. Drainage of the study areas was derived from digitized river systems of Nigeria watershed and more rectified within the GIS editing tools. Moreover, the spatial analyst extension line density modules were accustomed to calculate the drainage density of the study area. Line density computes the amount per unit area from polyline characteristic to descend inside a radius around each cell.

Table 7: Drainage Hazard classification

Drainage Hazard	Rank class	Density km/km^2	Area (km$^{2)}$	
Very Low	1	<14.75	498.76	65.52
Low	2	14.76 - 40.85	49.87	6.55
Moderate	3	40.86 - 61.27	76.60	10.06
High	4	61.28 - 85.09	110.51	14.52
Very High	5	>85.1	25.50	3.35

According to the classification method shown in Figure 9(b) and table above, an area with the higher value is very highly affected by flood and ranked to class five >85.1 km/km^2), high ranked to class four (61.28 - 85.09km/km^2), moderate ranked to class three (40.86 - 61.27km/km^2), low ranked to class two (14.76 - 40.85km/ km^2) and very low ranked to class one <14.75 km/km^2).

4.6 Final Flood Vulnerability Assessment

In Gombe metropolis, the bedrock, mainly consists of sandstones of cretaceous age, covered by tertiary and quaternary deposits. Gombe metropolis is a low-lying, undulating landscape sloping from Akko escarpment in the west to Liji hill in the east which is the highest point of about 500m. The metropolis is drained by some ephemeral streams and ravines which take their sources from the Akko escarpment and flow eastwards. The soils are highly ferruginous, formed as a result of intensive weathering of the basement rocks. (Amos *et al.*, 2015). The vegetation is of the Sudan savannah type, characterized by shrubs, scattered trees and grasses (Amos *et al*, 2015). A similar research by (Deepak *et,. al* 2020) affirms that region can be considered vulnerable to flood if it is both socio-economic and physical-environmentally vulnerable, and these concept prevent over estimation in many cases as a socio-economic vulnerable region may not be physically-environmental vulnerable. Thus, the socio-economic vulnerability (SV) was obtained from MCDA approach and the physical-environmental vulnerability (PV) from Random Forest method. The vulnerability to flood greatly depends on the physical-environmental factors, and are further modified by combing the socioeconomic vulnerability, so as to get a realistic picture of the spatial variation of vulnerability (Deepak *et., al* 2020). According to the result obtained based on the slope, elevation, rainfall, land cover, drainage density and soil factor, indicates that flood vulnerability is higher in southwestern part of Billiri followed by some part of central and northeast. Villages prone flooding include; Shela, Ayaba, Kwaya, Tudu, Talum, together with Lakarai, Latur in central part and Laushi daji, Sansani and Fagla in northeastern part. The above factors have been used to develop a flood vulnerability map by using GIS and AHP or multi-criteria decision-making techniques. The result of the analysis shows that about 34.41% and 19.17% of the study area have high vulnerability to Flood.

Pairwise Comparison

Pairwise method of MCDA(Multi Criteria Decision Analysis) uses Numerical algorithms to explain the suitability of meticulous effect on the origin of contribution criteria and this influence mutually through various mathematical or logical means of deciding disagreement. Using this procedure, the influence value range 1 to 9 was allocated to every factor with professionals to replicate their relation consequence. By the weighted linear combination technique, every map layer was overlaid in ultimate GIS spatial examination for flood vulnerable zone imitation. The relationship between a mathematical value and intensity of less importance was as follows: 1 equal importance, 1/3 moderate, 1/5 strong, 1/7 very strong

Table 8 Final Hazard classification

Cat	Priority/Influence %	Rank	(+)	(-)
Slope	31.80%	1	15.40%	15.40%
Elevation	19.40%	2	8.80%	8.80%
Rainfall	7.10%	6	3.10%	3.10%
LULC	17%	5	10.80%	10.80%
Drainage Density	18.30%	3	5.90%	5.90%
Soil	6.30%	7	1.90%	1.90%

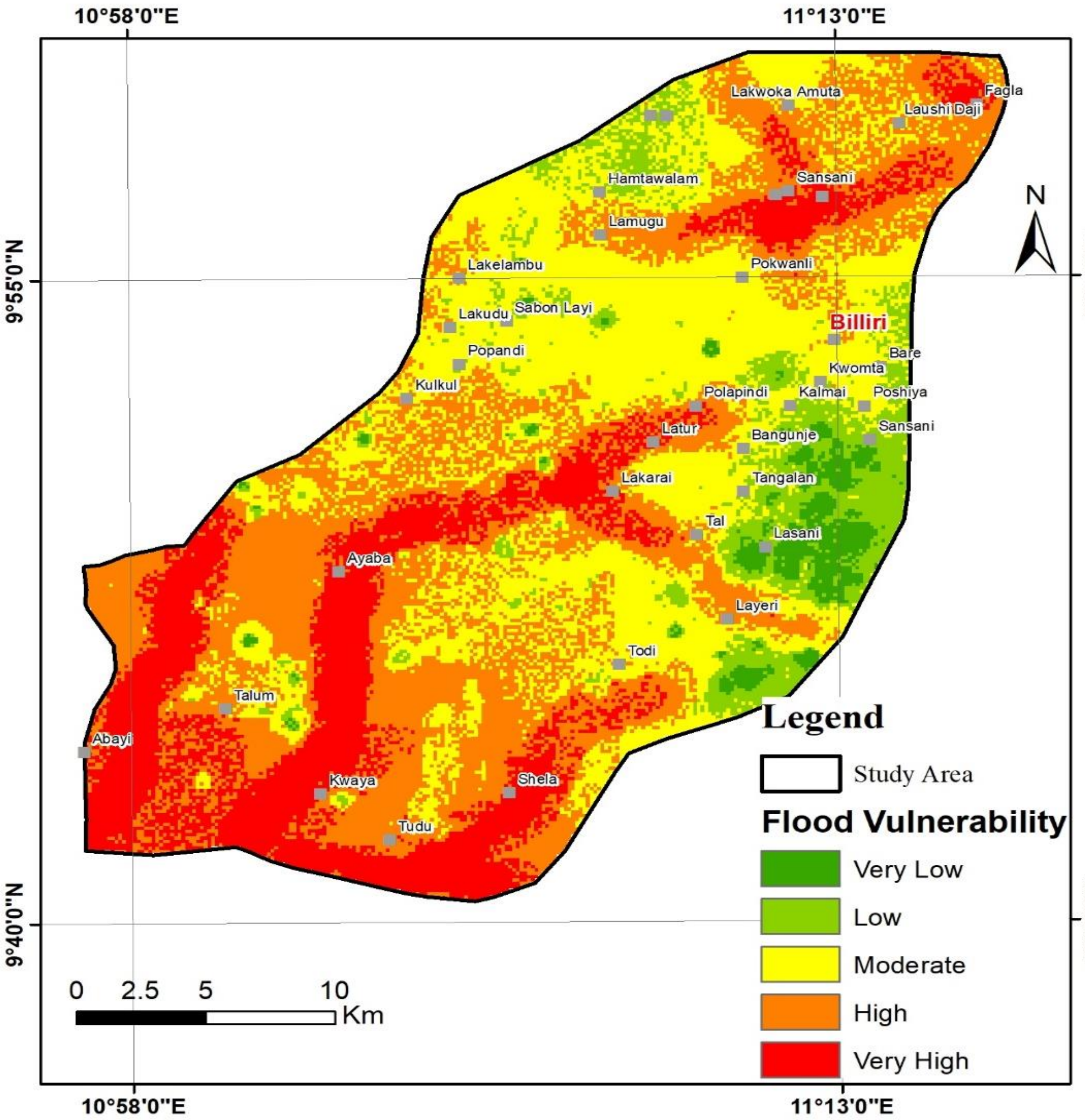


Figure 8: Flood vulnerability map

5.2 Conclusion

The number of flooding event globally causes more damage to the community and put lives at risk based on historical documents. This shows how vital flood assessment using GIS-based are. The result of this research is useful on improving flood mitigation and risk management strategies. The study assessed the flood risk in Billiri local government. Based on flood risk factors analysis, the results indicates that southwestern part of the study area is more vulnerable to flood. The flood mitigation measures required based on the research was creation of dams to control flood, proper channelization and the use of flood warning system. Considering the factors, the study used ArcGIS to map and model the primary and secondary data as parameters that contribute to flooding, the parameters include; annual rainfall, slope, soil type, elevation, drainage, land use and land cover factor.

5.3 Recommendations

1: Structural mitigation measures dam are creation, suitable drainage system, denaturalization of rivers, foolproof structures, floodplain of flood restoration.

2: Non-structural flood mitigation measures these include flood resilience, risk-based flood management evacuation, flood protection, soft measures, hard measures. Public awareness, flood fighting, sustainable flood management, flood risk zoning, spatial planning and environmentally friendly solution.

3: Flood warning system, these includes the use of GIS-based flood warning, sensor networks for flood detection, flood warning through media such as radio, TVs and phones flood, floodplain restoration, non-adverse impact approach, community operation, compensation, flood walls warning systems, public awareness, and suitable drainage system.

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