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MAPPING OF FLOOD RISK ZONES IN KAFANCHAN TOWN, JEMA'A LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

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ABSTRACT

Floods are defined as water disasters that causes temporal or permanent consequences in an environment. This research focused on the Mapping of Flood Risk Zones in Kafanchan town, Jema'a local government area by the utilization of field survey and GIS in other to identify and map out the flood prone areas in kafanchan. Multicriteria Method was used for evaluation of the flood risk areas by using various criteria like rainfall data, distance to road, drainage density, and slope. Findings revealed that heavy rainfall, inadequate drainage and slope are the major causes of flooding. From the findings the flood risk map identified places with high, moderate and low vulnerability. Results showed that flood disasters have detrimental effect on people and property. The flood tragedy significantly harmed the environment as well as socio-economic sector. In the research area, the threat of flood disaster has not been addressed by Disaster management/response organizations. Findings, however, showed that these initiatives are insufficient to reduce the threat and risk of flooding in the research area. This study helps government and policymakers in zoning to avoid future flood events from causing tremendous havoc in the study area and providing Early Warning Systems for the area.

Keywords: Flood risk, Drainage density, Disaster management, Kaduna state

INTRODUCTION

One of the worst natural disasters in the world, flooding destroys a great deal of property and takes lives (Adeaga, 2008). On a global scale 1980 and 2008 had an estimated 2,887 of flood events which accounted for the death of 200,000 persons, affecting 2.8 billion people and economic loss of USD397 billion (UNISDR,2013). From 2008 to 2020, floods were reported in Brazil, China, India, South Africa, Mozambique, Cambodia, Namibia and Nigeria having high fatalities and high property damage in each flood event, In both industrialized and underdeveloped nations (Kundezewicz et al., 2012, Afifa, 2020 & Slawson, 2020). Many countries have experienced the dire impact which natural disasters have on lives and properties. It has been demonstrated in research that managing floods more successfully occurs when maps of flood risk zones are combined with flood predictions. (Sarma,1996; Balogun and Okoduwa, 2000). These occurrences are brought by excessive rainfall, which causes runoff waters to rapidly accumulate and release from upstream to downstream. Flood is among the most common and destructive natural hazards, having a serious negative influence on people's lives as well as the global economy. (Khan *et al,* 2011). Knowing the size and evolution of floods is crucial since they pose a threat to both life and property, making them one of the environmental degradation issues. While total control over flood disasters is unattainable, flood damages can be reduced with the use of appropriate structural measures (Awosika and Folorunsho,2000). Flooding ranks highest among natural catastrophes in terms of both the number of people impacted globally and the proportion of particular infrastructure, such as buildings, drainages, etc., it is a cause for concern in the fields of hydrologic and natural hazards science. (Borga, Anagnostou, Bloschl & Creutim 2014).

In Africa, the countries in this region are prone to flooding not just because of the vulnerable location but also the lack of good infrastructures or physical planning, this mostly results to the encroachment of residential buildings close to the vulnerable locations and inability to prepare for, handle or recover from flooding (Adelekan, 2010). Between 1996 and 2020, floods are viewed as one of the most disastrous events on the African continent (Satterthwaite et al., 2007) within these periods a total number of 290 flood disasters were reported in West Africa, over 8,183 people lost their lives. The Niger Basin consisting of Guinea, Mali, Burkina Faso, Chad, Benin and Cameroon are the most vulnerable countries and that has resulted to the economic losses reaching $1.9billion (Satterthwaite et al., 2007). In recent events, 2020 recorded events of flooding in countries like; Ethiopia, Tanzania, Djibouti, Somalia, Kenya, Rwanda and Nigeria affecting at least 700,000 people, they began with heavy rainfall in March affecting massive flooding and landslides (Celetial,2020)

The basin authorities were charged with the task of flood control and erosion as well as water shade. There are various factors influencing flooding events they are, severe rainfall, climate change, construction of structure over drainages, inadequate drainage networks, and increase in population in urban areas. These elements interact, and flood disasters typically result from a number of them acting in concert (Adeoye, Ayanlade & Babatimehin, 2009). In addition, urbanization cause the conversion of agricultural land, natural vegetation and wetlands into built-up regions. It also causes development on natural drainage systems and increases the population of people who live in flood-prone places like river bottoms and flood plains (Adeoye *et al*, 2009). In addition to population growth and the continuous accumulation of valuable assets, climate change is predicted to increase flood frequency and amplitude in the future, raising the risk of flood that now exists in metropolitan areas (Julius, 2019).

In Kaduna, about 100 houses have been submerged in flood as reported by the Daily Trust Newspaper (29th August 2012) as a result of heavy rainfall. Flood danger is determined by several factors rather than past events; Precipitation, River flow and drainage density, modification to flood control brought about by building and development on flood plain regions. (Suleiman *at al.*,2014). Floods are generated by extremely heavy rainfall, which causes runoff waters to rapidly accumulate from upstream to downstream. Discharges swiftly peak and almost immediately decrease. Flooding ranks highest among natural catastrophes in terms of the number of persons affected worldwide and the percentage of individual fatalities, making it a worry in hydrologic and natural hazard situation (Borga, Anagnostou, Bloschl, & Creutin 2014). In many areas, the possibility of flood related deaths and property damage is rising as a result of social and economic development, which puts pressure on land-use, e.g., through urbanization. Flood vulnerability is predicted to rise due to the effects of climate change, extreme weather in the form of excessive rain and river discharge conditions (Dihn, Balica, Popescu & Jonoski 2012). Accurate spatial and temporal data on the possible hazards on the dangers of floods is therefore necessary to account for both current trend and future scenarios of flood risks. Chang and Guo (2006), have reported that heavy rainfall frequently cause flood in metropolitan areas.

Jema'a Local Government consist of various wards but the ward that has a major river flow is in Kafanchan, the river is called Hayyan Gada and residences that live close to this river experience flooding. GIS analysis was implemented in mapping out those flood risk zones.

Flooding around Jema'a Local Government is dependent on rainfall surplus that exceed the threshold of the river. Millions of naira worth of properties is being destroyed because of this disaster. Researches have been conducted to identify the reasons of flooding and most of the results show that flooding occurs due to anthropogenic activities such as disposing of trash in water ways; High intensity of rainfall; Dam failure/ overflow. Flood plains used to draw a lot of people since they were convenient water supply, transportation, power development and inhabitation particularly for low-income household (Ojigi and Shaba, 2012). Issues of development and poverty have led local communities and more people to live in areas vulnerable to flooding (Rosenburg, 2008). Rainy season is a time of concern for people in kafanchan especially residents living close to the River (Hayyan Gada) because in a case of intense rainfall the environment has a tendency to get flooded and many people would be affected, the lack of a flood risk map had cost the residents/business owners a great damage but generating a flood risk map would provide a solutions to minimize the extent to which residents incur losses in a case of future flood events.

MATERIALS AND METHODS

Study Area

Kafanchan is a central place in Jema'a Local Government Area of Kaduna State, which is situated in the southern portion of the state in the north central region of Nigeria. It lies between Latitude 9˚33' 30" N to 9˚36'30" N and Longitude 8˚16'0" E to 8˚20'0" E with and elevation of 742 meters above sea level. Kagoro located in Kaura Local Government Area, borders Kafanchan to the East in the South by Nassarawa State, Zonkwa and Ungwan Rimi District in the North.

The average annual temperature is about 25.2C with average yearly highs of 28.6C and the lows at 18.8C and an average humidity of 63.7%, similar to that of Kagoro. The Orographic effect of the Jos Plateau and the Kagoro hills has greatly influenced the temperature, rainfall and relative humidity of the area. According to (Abraham,2021) posited that, the region is influenced by a very sttong dry wind and the high plateau of Jos during the dry season, which runs from November through February and is when the country is under the effect of a Northeast Trade wind.

According to (NPC, 2006) Kafanchan as a population of 278,735 with annual growth rate of about 3% in the state, the 2009 projected population was about 335, 581. There are rich in good alluvial soil for carrying out agricultural activities; most of its residents are farmers who practice subsistence agricultural mostly, and keeping of animals. One of the most significant jobs in the region is Agriculture. The major crops grown in these areas are sorghum, ginger, millet, cassava and maize. Most of the farmers depend on rain for plant cultivation and in rare cases irrigation. Kafanchan is a town which was formally a junction station of the Nigerian Railway Corporation (NRC) and it connects to places like Port-Harcourt, Enugu, Bauchi, Kuru and Maiduguri(Maurice,2006). A place like Kafanchan is dominated by Koninkon People known as The Nikyop but also it harnesses various ethnicity like Igbo, Yoruba and others(KDSG,2021). The diagram of Kafanchan in Figure 1

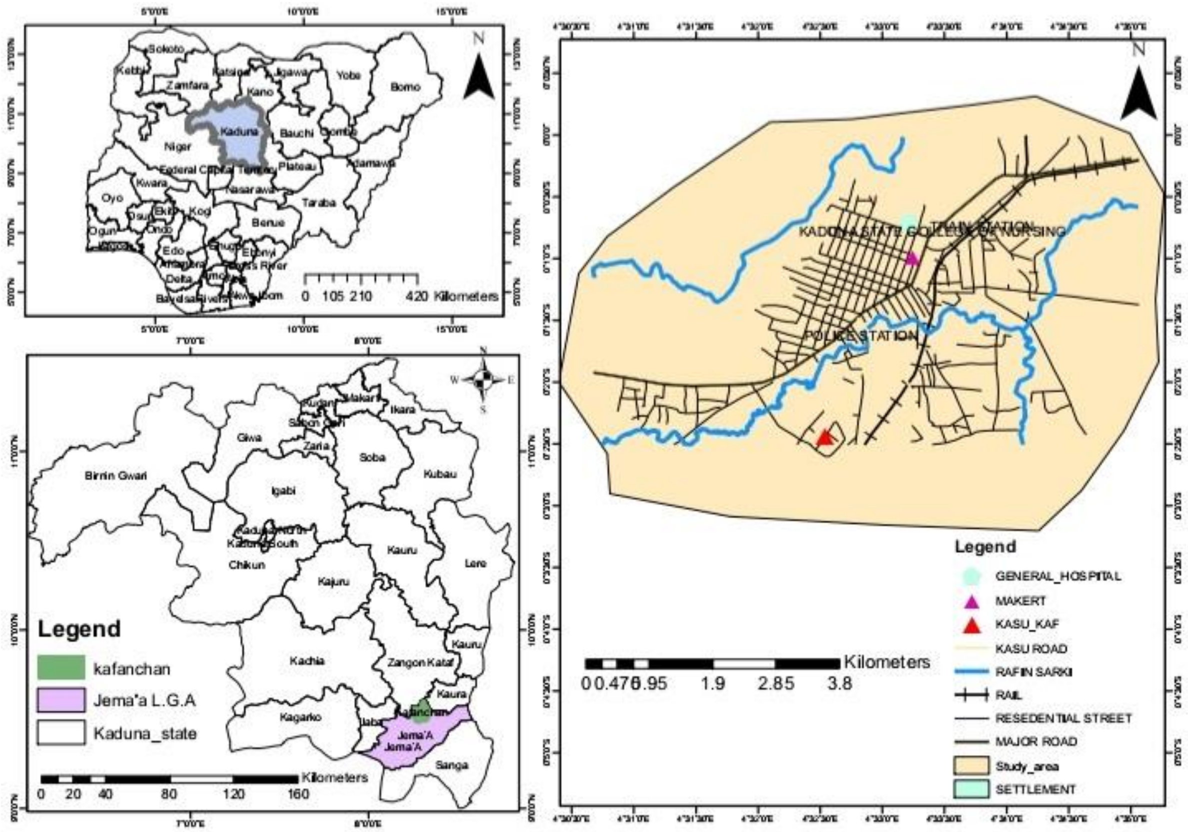

Figure 1: Map of Kafanchan showing River (Study Area)
Source: Field Work, 2023

Types and Data Sources

In other to achieve the set objectives data was employed from two major sources which are: Primary Sources: The primary sources were generated through field survey, DEM Files from USGS and use of GIS, Digital map which helped in extracting water bodies in the study area. Secondary Sources were obtained by reviewing relevant literatures from documents such as journals, seminar papers and Satellite image.

General Framework

This research focused on obtaining Digital Elevation Model data containing elevation of Kafanchan. The imagery ArcGIS interface was utilized to generate slope based on the imagery, other analysis like the drainage was produced with ArcGIS's hydrology tools. The analysis of the flood risk zone was achieved through the evaluation of certain sub-criteria like rainfall, distance to road, etc. and verifying the criteria that plays the most part in the event of flood within the research domain, this is achieved through the combining all of the criteria using spatial analyst tool on the ArcGIS interface which overlapped to create a flood risk map and identify the high, moderate and low exposure zones.

RESULTS AND DISCUSSION

Analyzing of Rainfall Data for Kafanchan for 2020

For the purpose of this research the rainfall data of Kafanchan Ward A and B was downloaded, the ArcMap software was launched and the annual rainfall data was inserted into the software the annual rainfall data was downloaded from CRU Data website in a zip file format which was extracted. Arc toolbox was launched and multi-dimensional tool was open and netCDF raster layer Tool was selected to process the rainfall data of Kafanchan 2020.

The rainfall data was projected to UTM projected system to extract the annual rainfall data of Kafanchan wards as the study area of interest, a new layer was generated in the ArcGIS environment and the study region's shape file was imported

Processing the Rainfall Data

One of the main causes of floods is high rainfall, flooding usually results from heavy rainfall when water banks cannot hold enough water to prevent capacity overflows. Flooding is extremely at its most destructive when there are lots of poor infrastructures and water which cannot seep to the ground basically flows as runoff.

To carry out rainfall analysis, add the rainfall data by clicking on connect to folder on the ArcMap interface then double click on the Annual rainfall data that was already downloaded from USGS. The data was opened and then transported to the Arcmap interface and there were 120 different panchromatic layers but for this analysis the band 109 to 120 were selected to process the study's yearly rainfall.

The arctoolbox was utilized to extract the data on the ArcMap interface, the clicking on the spatial analyst tool and finally clicking on the extract icon. Local tool box was lunched then the cell statistics was used and the overlay statistics was change to sum simply to calculate the annual rainfall of the region. The raster data was converted to point by using the conversion tool box this was achieved by opening the conversion tool and converting raster to polygon icon the toolbox was used to convert the cell statistic data to point data to process IDW Analysis. The precipitation data which was converted from raster to points was then interpolated to see areas with equal annual rainfall distribution in the research region this result was carried out by opening the arc tool box and spatial analyst tool and the interpolation toolbox was open

IDW toolbox was used to process the analysis. The raster to point data was added at the input feature column gridcode was used for z value the output cell of the output data was 30metre because the land sat data was in 30 meters' resolution finally the annual rainfall data of Kafanchan result was achieved symbology of the result was adjusted to four classes See and three columns to have a standard value.

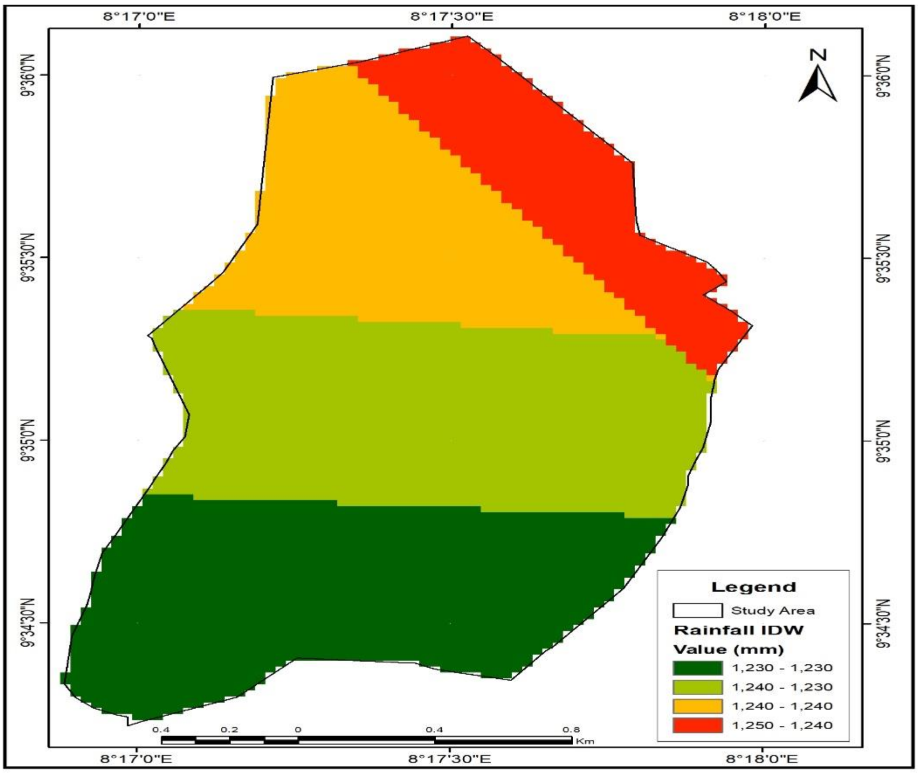

Figure 2: Map showing Rainfall of the Study Area
Source: Author's field work 2023

From the Fig 2 we can see the rainfall is almost equally distributed in Kafanchan, places with value 1,230mm are places of very heavy rainfall these are the places that are most prone to flooding, value 1,240mm are places of heavy rainfall which indicates their vulnerability to flooding and value 1250mm are places of medium rainfall.

Drainage Density

Downloading the Digital elevation data

The DEM data was provided from United States Geological Survey earth explorer website SRTM 1 Arc-Second Global was selected to acquire the DEM of the field of study which was 30m resolution or cell size, this data was used to produce and analyses the drainage density, Slope, Elevation, close to road, close to river and the close to road of the research region as criteria to analyze the flood risks of the field of study respectively.

Drainage Density Analysis

From Fig.3 below the DEM data was inputted and computed in the ArcGIS environment by extracting the area of interest (A.O.I) using the extract by mask techniques. Low drainage density is typically found in high permeability soil and high density vegetation. The drainage density is the ratio of the total length of streams in the shed over its contributing area, and it affects water output and sediments from the water system: Areas with little vegetation and impervious surfaces have high drainage densities. From the map below the places of very low drainage density have values ranging from 0-401.06m, low drainage ranges from 401.06- 1097.2m, while moderate drainages range from 1097.3- 1536.1m and high drainage density ranges from 1536.2- 1926.6m.

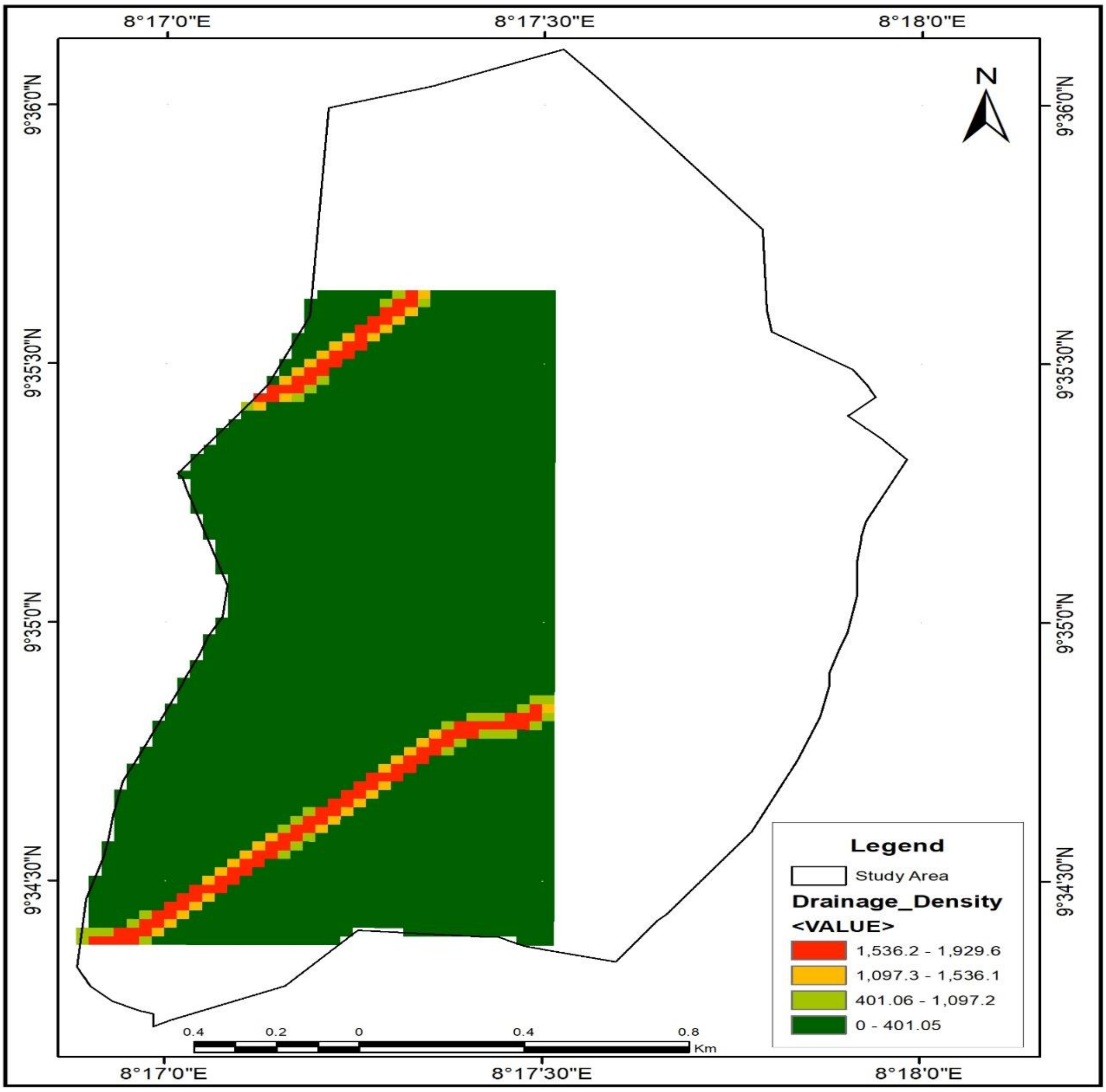

Figure 3: Map showing Drainage Density
Source: Author's Fieldwork 2023

Flow Accumulation

After opening the flow accumulation toolbox, the flow direction layer was entered into the raster data column, the data was processed and a new layer was generated as flow accumulation in the table of content as a layer see fig.4 below. The flow accumulation calculates a raster of accumulated flow in each cell. The multicolored lines basically indicate the flowing accumulation point of the water on the elevation image.

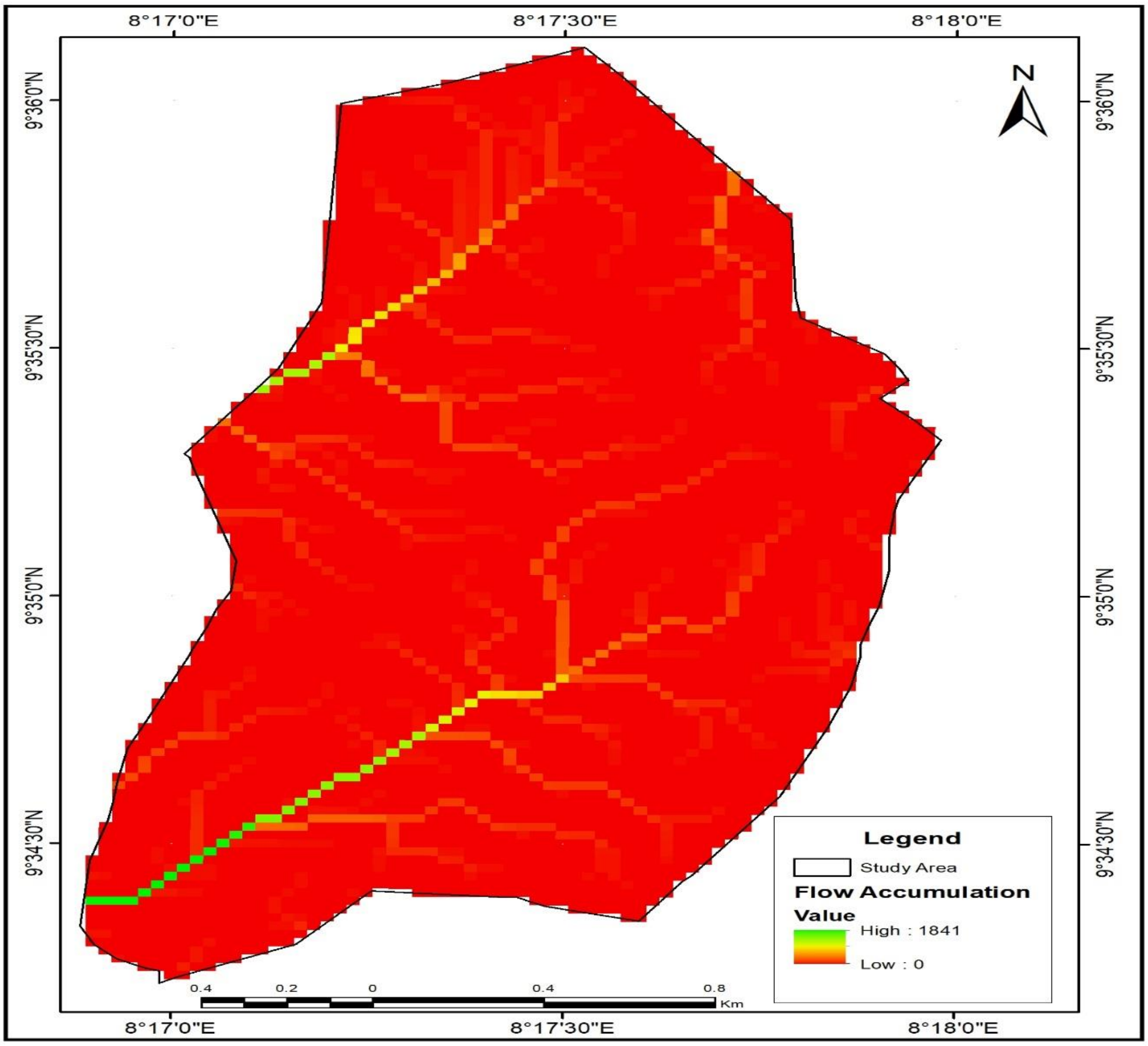

Figure 4: Map showing Flow Accumulation of Study Area.
Source: Author's Fieldwork, 2023

Elevation
The height, length of the drainage and the elevation in the research region were determined using the raster calculator, to open the raster calculator open map algebra and double click on Raster Calculator. A table will pop up with arithmetic, string, column and other geometrical symbols to do calculations Double click on flow accumulation and click on greater than equal to symbol then Type the value of the highest elevation from the DEM and click on ok button. A new layer was generated with a value of 0 and 1 it means that the places with 0 values are below the elevation of the research region and the 1 value means rivers or streams respectively see figure 5.

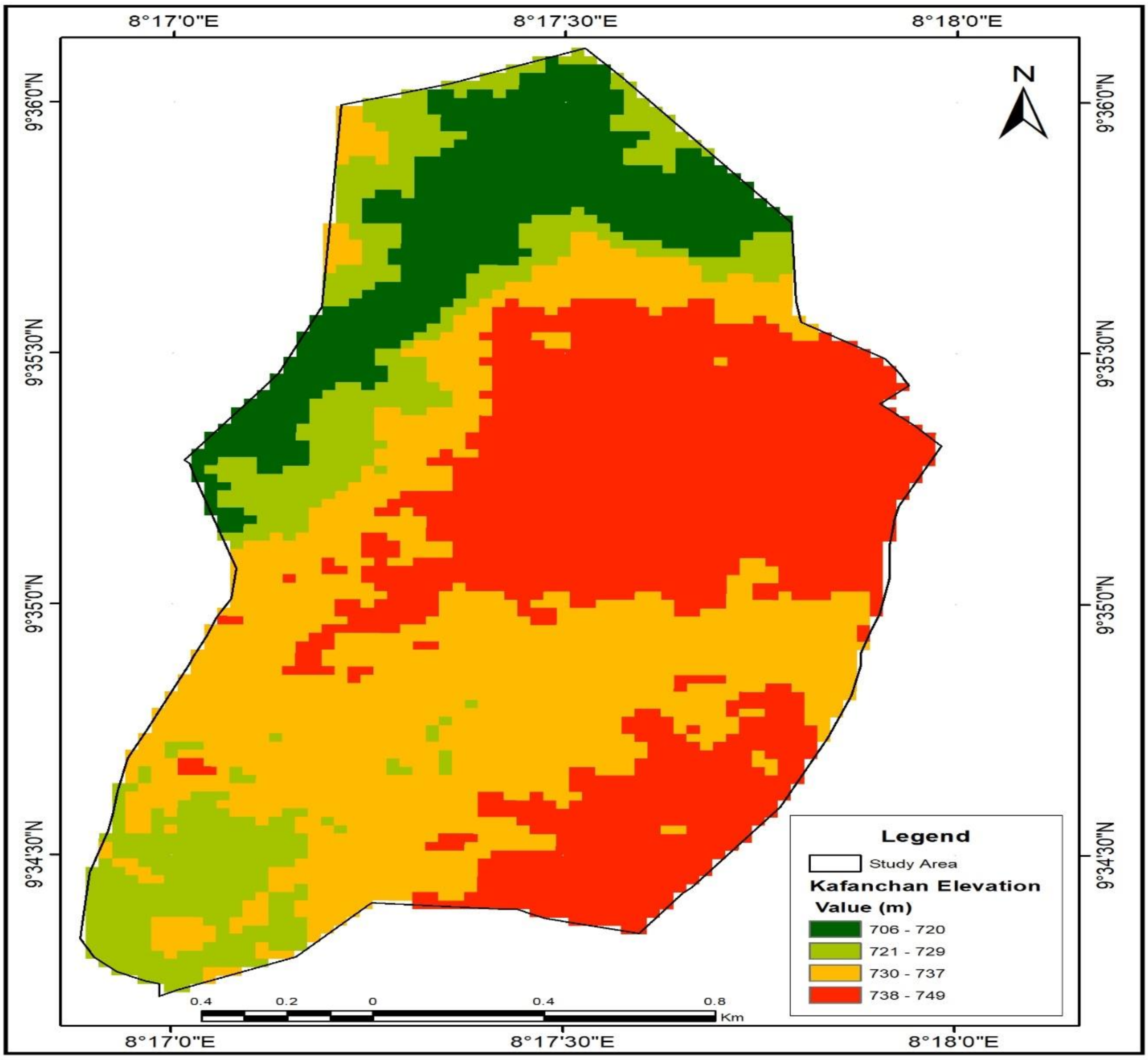

Figure 5: Map showing Elevation of Research Region
Source: Author's Field work 2023

Distance From Road Analysis

From Fig.6 below This analysis was achieved by digitizing all the roads in the study area using Google Earth application software which were digitized as paths and save as kmz file format, the kmz file format where then inputted into the ArcMap environment using the arc tool box conversion tool and then converted from kml to layer techniques. the analysis used buffering to delineate the distance of the road to the river at a 10m mark.

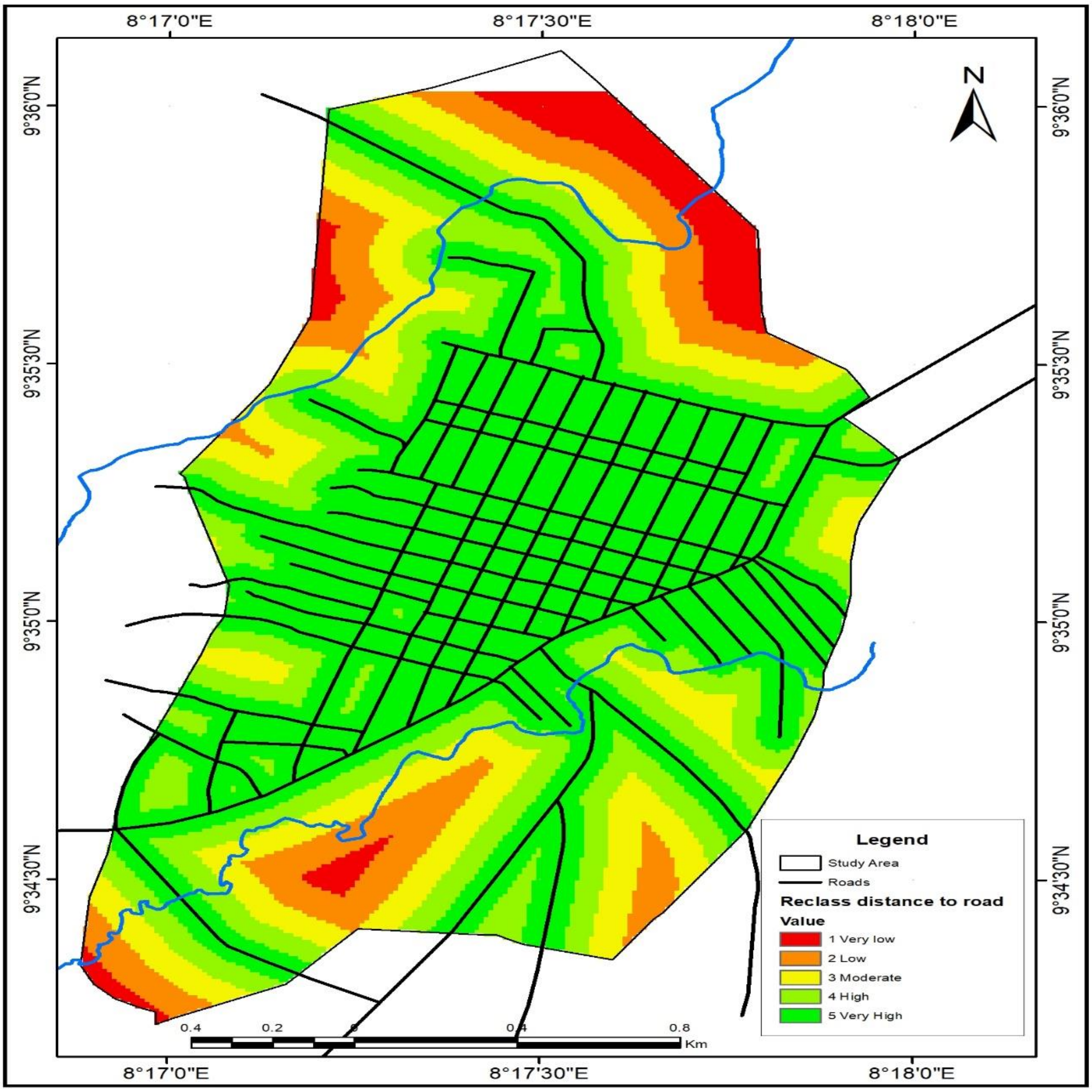

Figure 6: Map showing Distance to Road
Source: Author's fieldwork, 2023

The spatial analyst tool box was utilized calculate distance from road using distance tool in a Euclidean distance and the result was reclassifying to five classes to a raster file format. From the map the road distances marked 1 and 2 are not likely to be affected by flood because the road networks are few in comparison to the places marked 3,4, and 5 this is because there are more road networks which are close to the river and as a result can be affect by flood.

Distance From River

This analysis was achieved by digitizing all the river in the study area using Google Earth application software which where digitized as paths and save as kmz file format, the kmz file format where then inputted into the ArcMap environment using the arc tool box conversion tool and then converted from kml to layer techniques a total of 2 notable river were seen in the field of study.

Using the spatial analyst tool box, the distance from river using distance tool in a Euclidean distance was determined, the analysis used buffering to delineate building close to the river at a 10m mark and the result was reclassifying to five classes to a raster file format. Fig.7 shows that the distance of buildings to the river area, places from value 1-3 are areas farther away from the river while places marked 4-5 are places closest to the river.

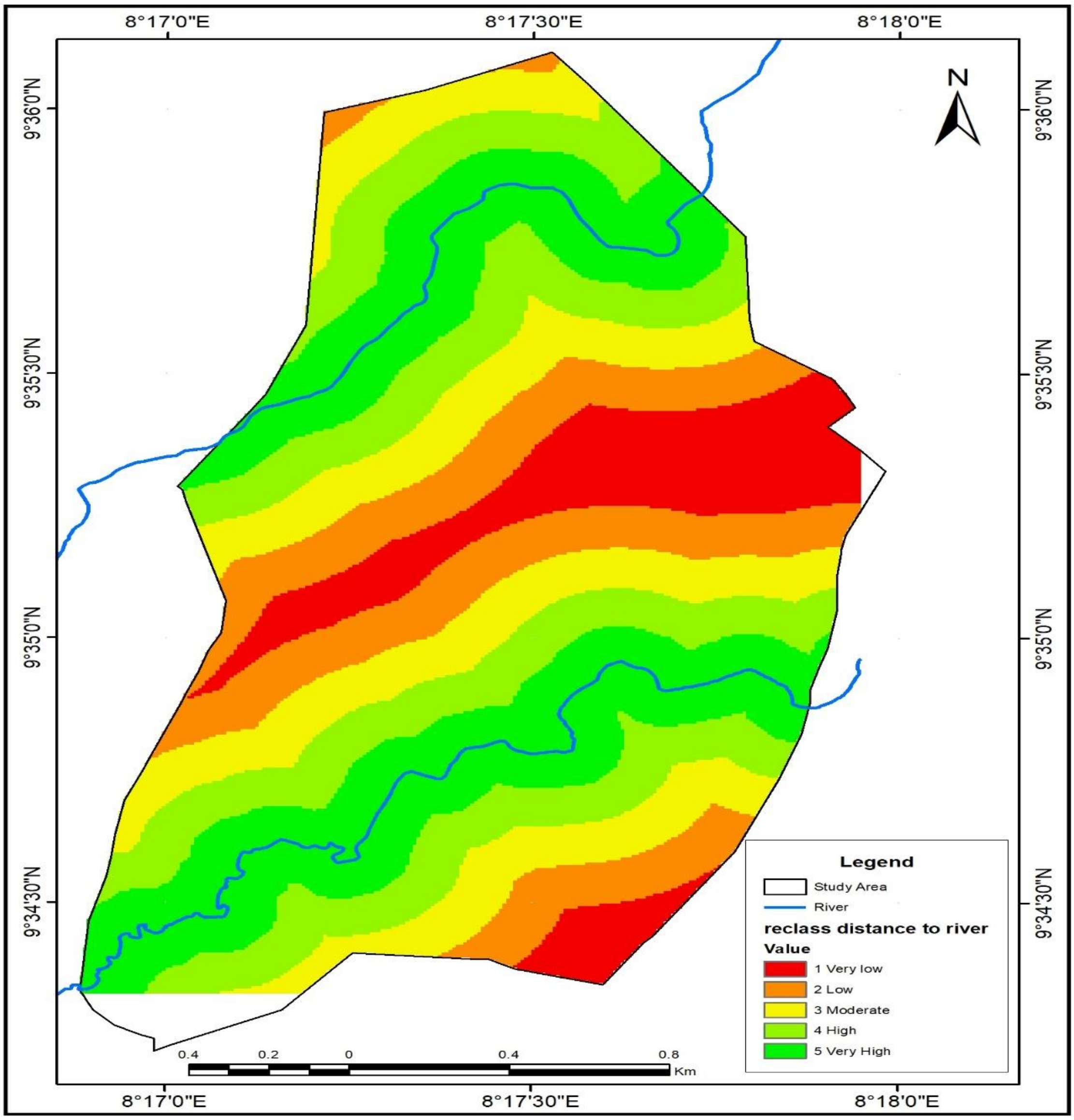

Figure 7: Map Showing Distance of River in the Study Area
Source: Author's fieldwork, 2023

Slope Analysis
The steepness strongly influences flow direction, run off velocity and amount of water from drainage reaching site is called Slope. Flat terrains are vulnerable to water logging whereas steeper slopes are vulnerable to surface runoff, slope of the study area was achieved using the SRTM data which was used for drainage density map the slope was produced using the ArcMap environment from the arc tool box spatial analyst tool box, the surface toolbox Slope tool was utilized to determine that the slope of field of study was 3 to 26. Fig.8 below shows the slope of the study region.

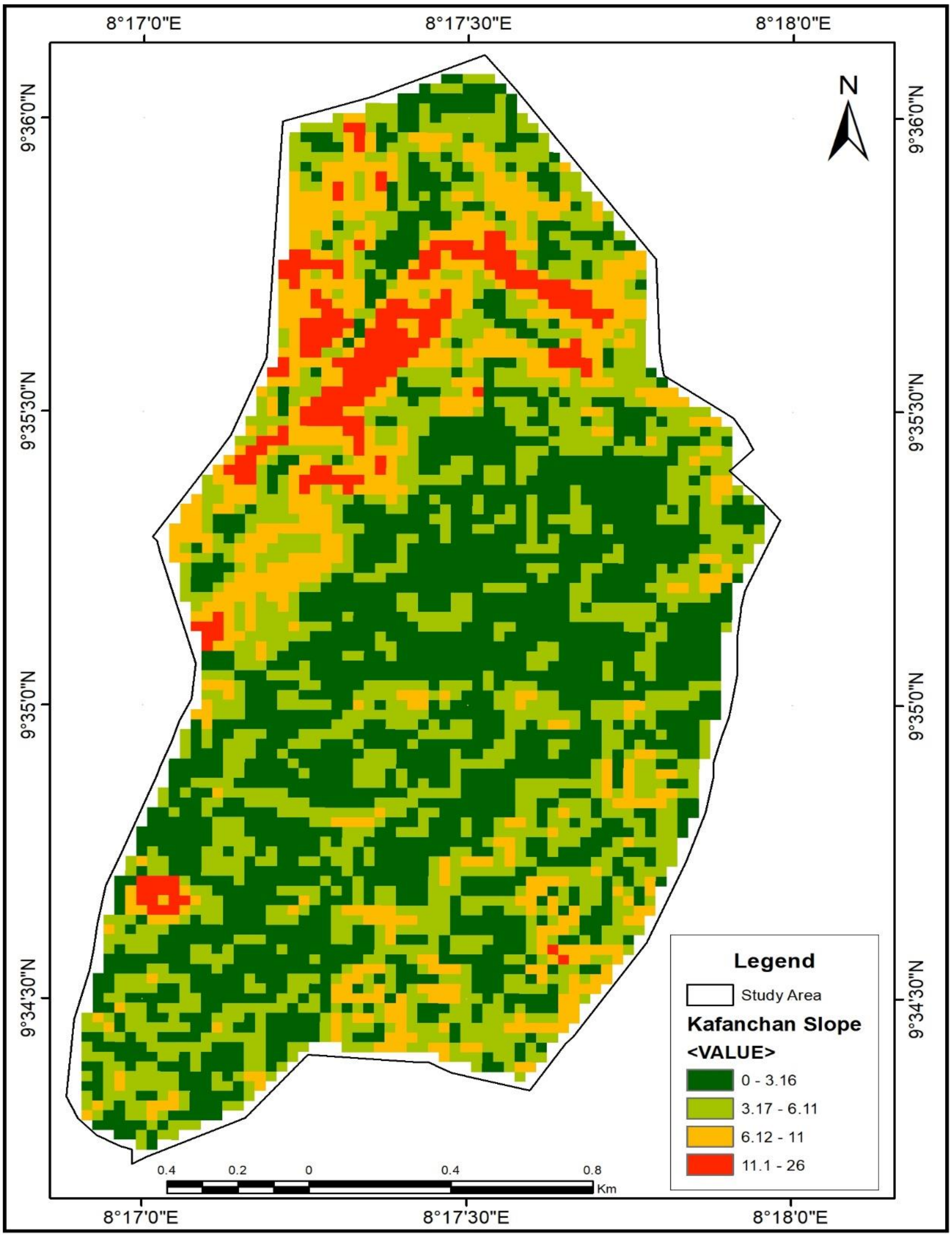

Figure 8: Map showing Slope in Study Area
Source: Author's Field work, 2023

Analysing the Criteria to Produce the Flood Risks Map
A total of six (6) variables was used to generate the flood risks of Kafanchan Ward (A and B) this data includes the drainage density, rainfall intensity, distance from river, distance from roads and elevation and lastly, the slope of the study area. The white space areas are those areas that would most likely be less impacted by flooding because they are the most furthest from the river. The risks analysis was measured in five categories that is 1 to 5 classes i.e. (Very high, high, moderate, low and very low) flood risk in the study area using the chloroplate mapping to show places with high to lower flood risk analysis mapping in the research region. Fig.9 shows places with high vulnerabilities are places close to the river.

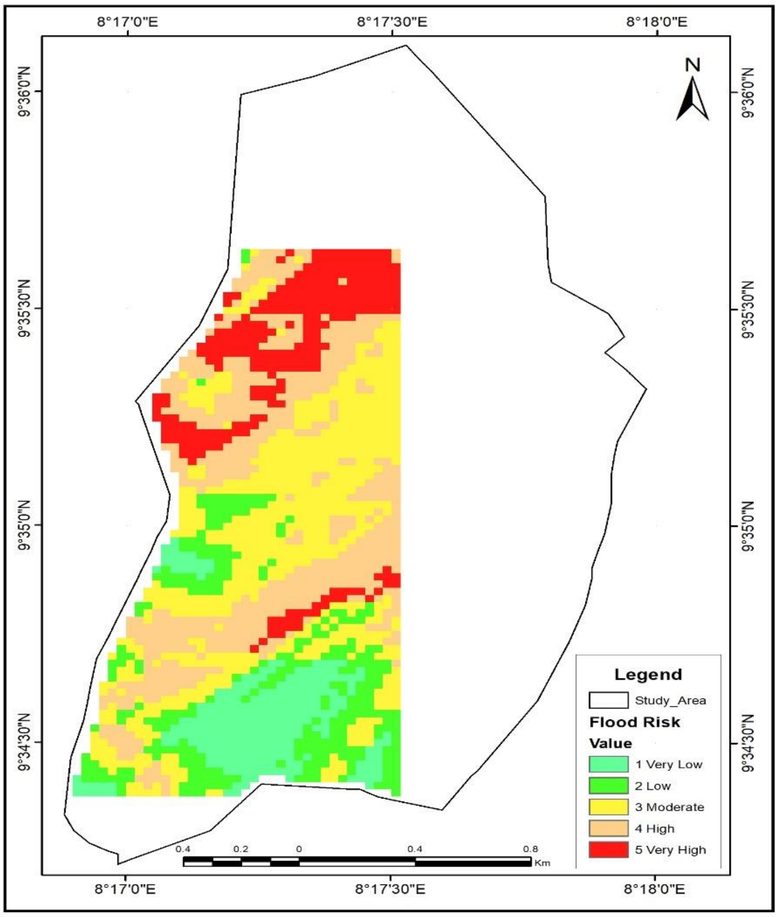

Figure 9: Map showing Flood Risk areas in Study Area.
Source: Author's Fieldwork, 2023

Spatial Analyst tool box was used to show places with flood risks, the overlay and weighted sum tool box was used to provide the data. The rainfall data was added to the ArcGIS interface then the distance from river, drainage density data, elevation data, slope data and distance data were added to see the result of flood in field of study after which the data was processed and a new layer was generated in the table of content with a number of 5 classes in a raster format to adjust the rate of risk associated with the data. Rainfall data was 30%, distance to river was 25%, Drainage density was 15%, Elevation was 15% Slope was 10% and Distance to Road was 5% respectively. The data was processed on a new layer and reclassified.

CONCLUSION

The menace termed as Flood is one incident that occurs on a Global, National and Regional which is the reason why it should be treated with a sense of urgency. The fact that the flood disaster occurrences are often sudden, and not well prepared for, poses substantial hazards and damages to socio-economic and environmental elements of the study region in terms of loss of life, property damages, displacement of people, interruptions of socio-economic activity, and environmental degradation. Although the flood tragedy in the study region is flash flood, produced mostly by heavy rainfall which cannot be halted, the risks of the flood disaster can be managed by the use of flood risk maps as one solution. It is hoped that the proposed precautionary and preventive measures can limit future occurrences, dangers, unfavorable effects and menace of flood disaster in the research region, as well as enable the inhabitants in the flood prone areas to live with the flood and appropriate its good affects. The research was able to produce flood risk map using DEM, which identified vulnerable regions as those that are quite close to the riverbanks and areas that have poor soils which does not facilitate percolation of water.

RECOMMENDATIONS

The study revealed several causes of flood disaster in the studied area such as heavy rainfall, improper waste disposal, and soil type which has affected lives and properties with its effect being visible in businesses and infrastructure, it is clear that a number of strategies can be followed to lessen the detrimental impacts of the adverse effects of the recurring event and provide feasible solutions to the problems of flood disaster.

It is however, based on the findings of the study's that the following solutions are advised:

i. The present situation of the affected areas in terms of inadequate drainage facilities is contributing to the risk of inundation of the areas. Adequate and well-structured drainage facilities should therefore be provided and maintained properly.
ii. People should avoid erecting buildings along water ways (this is seen along GDSS road especially) and are highly encouraged to remain away from river banks and channels, especially during rainy season peak, to minimize the chance of being submerged.
iii. Government and other stakeholders concerned (management/response organizations, civil society

groups, victims etc.) should enact laws that prohibits residents from disposing waste in Raffin Sarki.

iv. The current disaster management strategies are skewed only towards the issuance of emergency responses (mainly distribution of relief materials) to the victims. However, there is a tremendous need for all stakeholders to enhance commitments on flood preparedness and preventive measures using flood risk maps as one major instrument to improving land use zoning.

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