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Flood Risk Assesment of Zaria Metropolis and Environs: A GIS Approach

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Delineation of flood prone areas within Zaria and environs was carried out. Spatial data such as elevation, slope, wetness and drainage distances was used to delineate flood prone areas. These data were reclassified and weighted using Analytical hierarchy procedue-multi criteria evaluation method. The resulting flood risk map reveals the central and north eastern part of the study area as highest flood risk zones, while the southwestern part of the study area as the lowest flood risk factor. Areas delineated as having very low flood risk account for 28.3% of the study area and covers some 86.88 km^2. Areas delineated as having low flood risk accounted for 29.5% of the study area and covers 90.56 km^2. Areas depicted as having high flood risk accounted for about 32.1% covering some 98.545 km^2. Areas depicted as having very high flood risk accounted for 10% of the study area and covers an area extent of 31.007 km^2. Future infrastructural development must be guided by technical reports forecasting high risk, flood prone areas.

Keywords: Zaria; floods; spatial model; risk; development.

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1. INTRODUCTION

The world have experienced an increasing impact of disaster in the past decade. Many regions are exposed to natural hazards with unique characteristics. In Tropical Africa, one of the most common hazard is flooding, due to the severe impact of climate change. Flooding represents a severe human hazard [1]. And are among the most recurring and devastating natural hazards impacting human lives and causing severe damage throughout the world [2]. Majority of floods are harmful to human settlements and yearly flooding on average victimize 20,000 lives and affect 75 million people [3]. It is understood that flood risk will not subside in the future and with the onset of climate change, flood intensity and frequency will threaten many regions of the world [4]. The Intense rainfall is the key factor influence on floods, however, some other factors like geomorphological features, siltation, and land use pattern contribute to create floods. Flood impact is more pronounce in low lying areas due to rapid growth in population, poor governance, decaying infrastructure and lack of proper planning and management [5]. For years, flood management studies have been expensive and unwieldy, with much of the analysis performed by hand using papers. Recently, the advancement in computer aided technology has been extensively used in formulating models used for flood calculation and hazard analysis [6]. Use of GIS, GPS and Remote Sensing are helping flood managers to create accurate flood hazard maps with improved efficiency and speed at reasonable cost. The main advantage of using GIS for flood analysis is that it does not only generate visualization for flooding but also creates a potential to further analyze these events to estimate the probable damage due to flood [7]. Flooding in most Nigerian cities is a major environmental challenge that has continued to defy solution as more people are rendered vulnerable to hazards involved [5]. In 2012, Nigeria experienced an unprecedented flood that affected about twenty seven states, killed three thousand people and displaced about two million from their home. Though Zaria was not affected that much Zaria have often experienced small scale flooding. The probability of Zaria experiencing large scale flood is high due to the low lying nature of the terrain, present of large river and changing weather patterns due to climate change. Because of this threat cause by flooding it is necessary to identify potential areas likely to be affected by floods. Identification of such areas will aid in proper decision thus enabling government authorities to reduce the effect of flood in this strategic Nigerian city.

1.1 Location

The study area is located on the Crystalline Province of Northern Nigeria, within the Guinea Savannah belt. It is located on the Federal Surveys 1:50,000 Series Topographical Sheet 102 Zaria SW, between Latitudes 11°02ˈN to 11°10'N and Longitudes 7°38ˈE to 7°50ˈE (Fig. 1).

The topography of the area is generally low. Accessibility to the study area is possible through major road linking Zaria to Kano in the Northwest. Minor roads links most towns and villages. Accessibility within the study area is also possible through numerous footpaths.

2. METHODS

The methodology for delineating flood prone areas with Zaria and environ is presented on Fig.2. Method involves weighting and integration of different thematic layers relating to flooding using predictive modelling GIS. In this study flood risk map was generated with the aid of spatial data such as Shuttle radar topographic mission Digital elevation model (SRTM DEM) and satellite imageries (Landsat ETM). Digital elevation model was downloaded from website of university of Maryland Global Land cover facility website. Elevation, slope and drainage data were extracted from downloaded digital elevation model. Satellite images (Landsat ETM) was downloaded from Website of University of Maryland Global Land cover facility website. Wetness information was extracted using Envi software by running the tasseled cap algorithm. Multi criteria evaluation was used to assigned weight to different thematic classes within each spatial data.

2.1 Slope

Slope of any area has high influence on flood. Flat areas are more prone to flooding than steep areas. Using Arc GIS software, slope data was extracted from Shuttle radar topographic mission Digital elevation model followed by reclassification into five classes (Fig. 3). Weighting was then carried out using Ahp-Multi Criteria Evaluation (Table 1). Flat areas were given a higher weighting than steep areas.

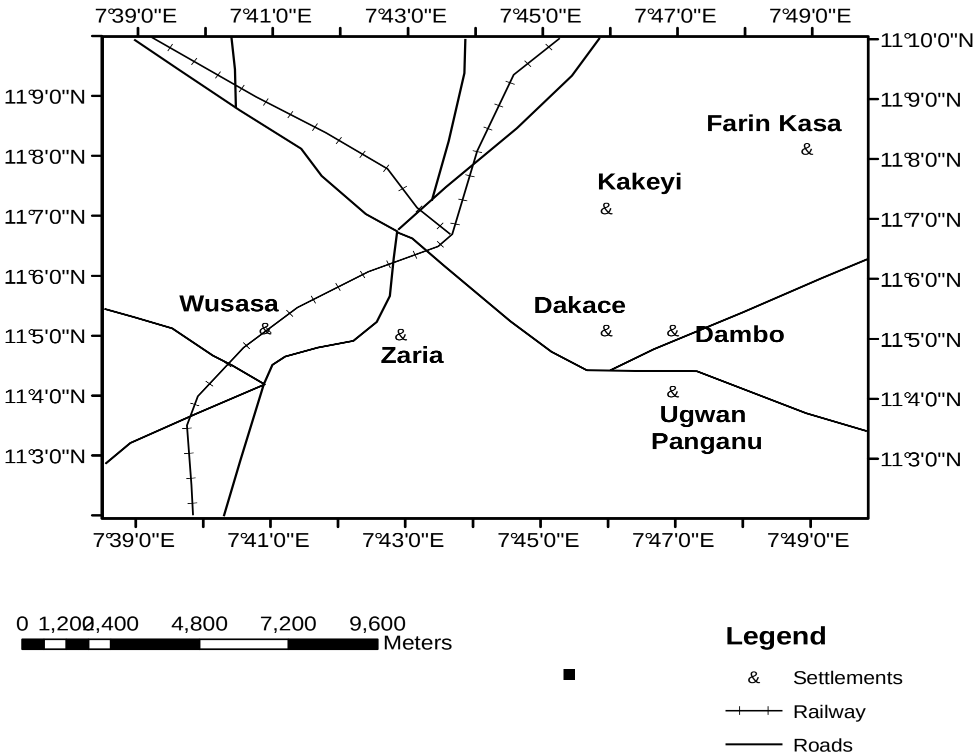

Fig. 1. The location map of the study area

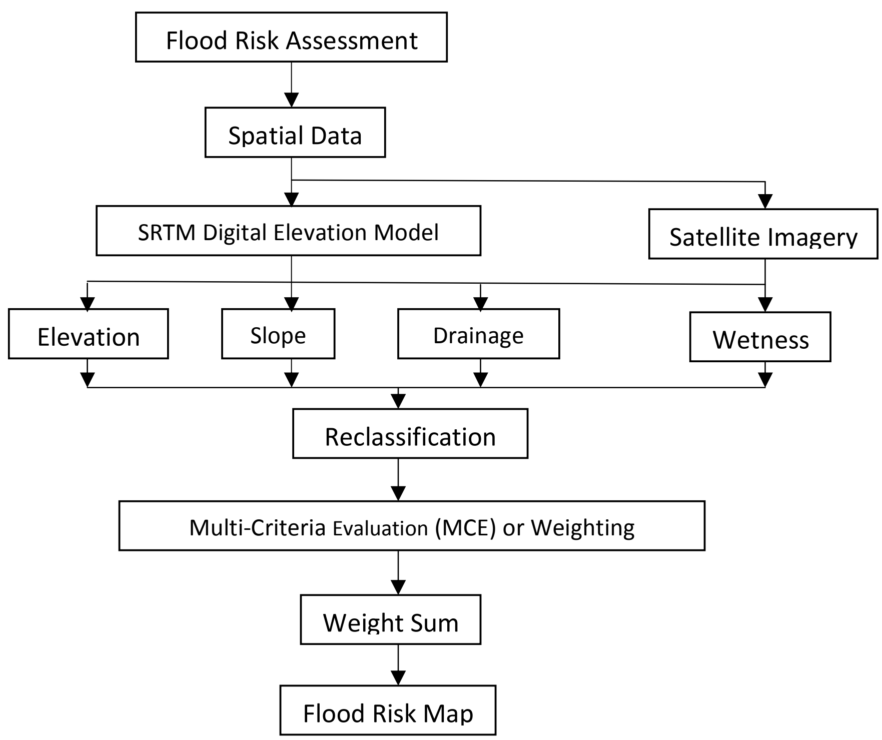

Fig. 2. A flow chart of the methodology adopted in the study

Table 1. Weighting for slope within Zaria

S/N	Slope	Weighting
1	Steep	43
2	Moderate	27
3	Gentle	18
4	Flat	8
5	Very flat	5

Consistency ratio =0.03

2.2 Elevation

Flooding generally affect low land areas, therefore elevation can be considered as an important determinant of flooding. Elevation data were extracted from Shuttle radar topographic mission Digital elevation model (SRTM DEM) using Arc GIS software. The classification into four classes of the elevation data was then performed (Fig. 4). Weighting for each class was assigned using Ahp-multi criteria evaluation. Low lying areas susceptible to flooding were given higher weighting than high lands (Table 2).

Table 2. Weighting for elevation within the study area

S/N	Elevation	Weighting
1	Extremely high	55
2	High	23
3	Moderately high	14
4	Low	8

Consistency ratio = 0.02

2.3 Distance to Drainage

The distance to drainage is considered as a very important factor when it comes to flood modelling. Areas that are close to drainage will be more prone to flooding than areas further away from drainage. Using the Shuttle radar topographic mission Digital elevation model (SRTM-DEM), drainage was extracted with the aid of GLOBAL MAPPER 17.0 software. The drainage shape file was exported into Arc GIS where buffering was performed. Reclassification and weighting was later performed (Fig. 5). Areas closed to the drainage were given higher weighting than areas further away from the drainage (Table 3).

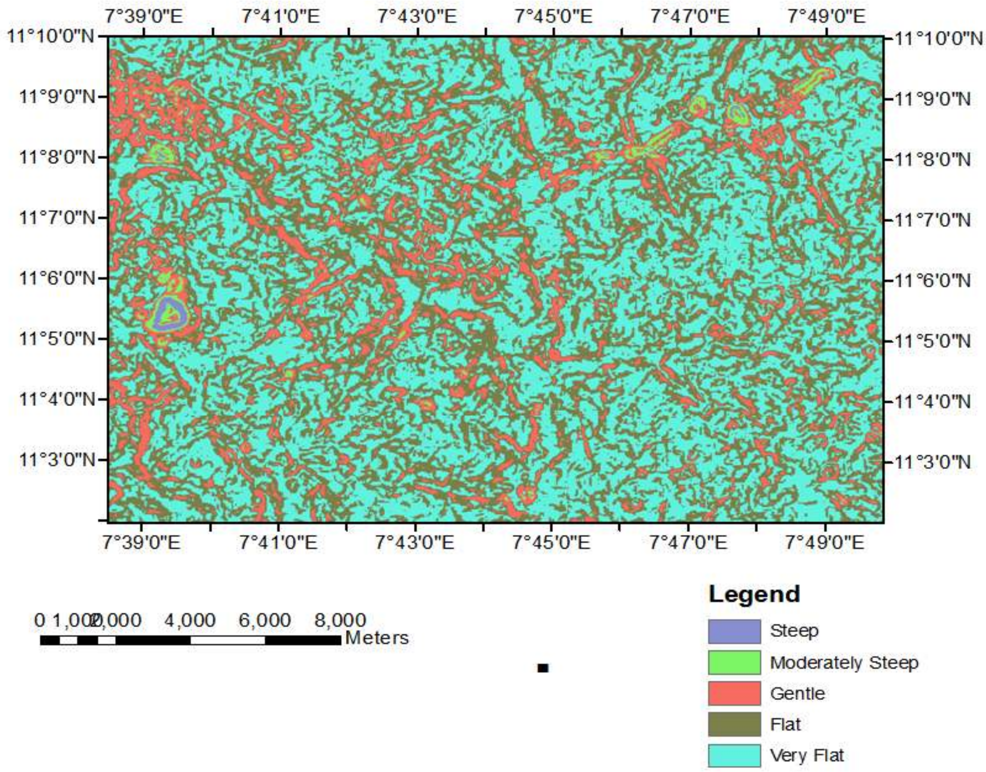

Fig. 3. Slope map within the study area

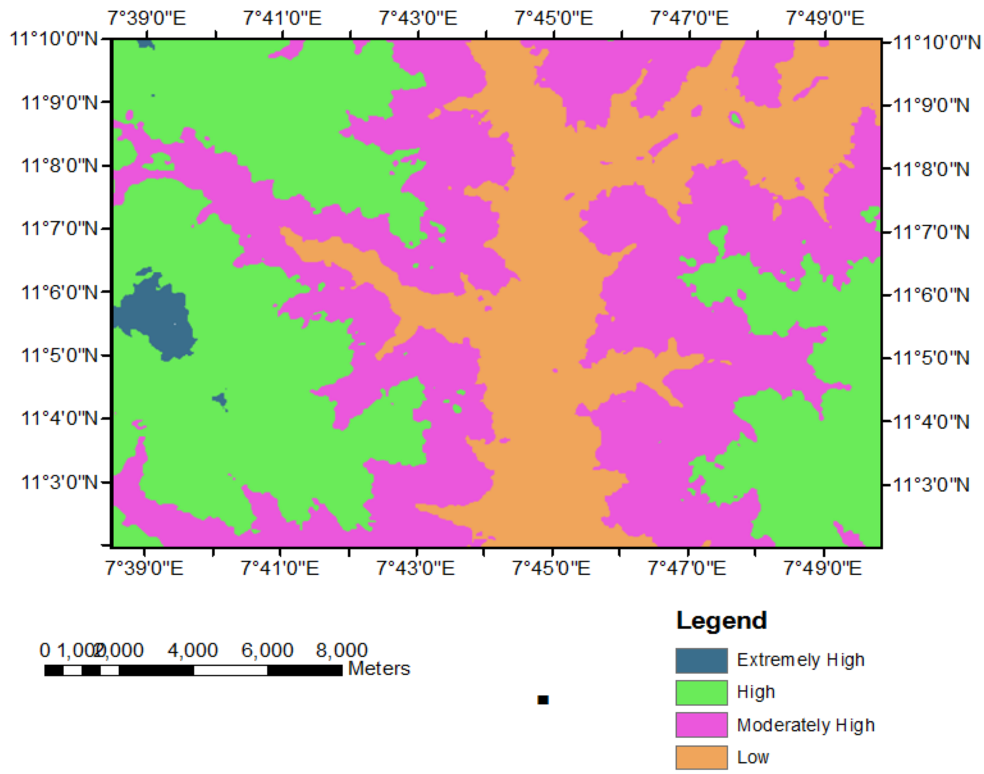

Fig. 4. Elevation within the study area

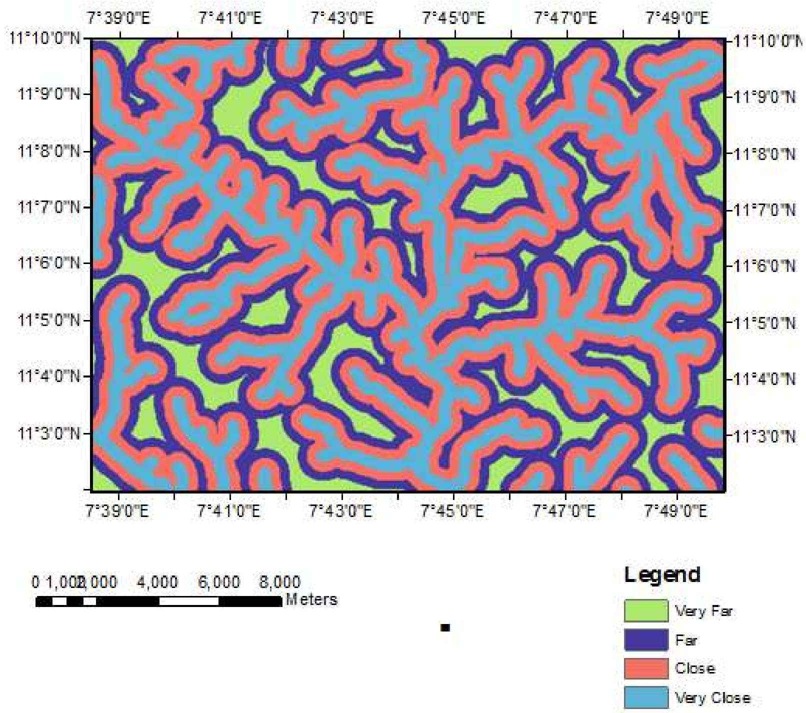

Fig. 5. Buffer map for drainage in the study area

Table 3. Weighting for distance to drainage

S/N	Buffered distance	Distance to drainage	Weighting
1	200	Close	57
2	500	Far	22
3	800	Very far	14
4	2000	Extremely Far	7

Consistency ratio = 0.04

2.4 Wetness

The degree of moisture in flood prone areas is very high due to its ability to retain water for a long period of time. Information on wetness for the study area was acquired by processing Landsat images using Tasseled Cap technique on ENVI 5.0 software. Wetness information was exported to Arc GIS software where classification was performed (Fig. 6). Using Ahp-Multi criteria evaluation technique, areas with higher wetting were given higher weighting than areas with lower wetting (Table 4).

Table 4. Weighting for wetness

S/N	Wetness	Weighting
1	Extremely wet	51
2	Very wet	22
3	Wet	15
4	Dry	7
5	Very dry	4

Consistency ratio = 0.02

2.5 Flood Risk Map

After the generation and classification of individual layers related to flood, a flood risk map was eventually produced by combination of slope data, elevation data, Drainage distance data and wetness data using the following formula below. Integration of this data was made possible with the aid of Arc GIS 9.3 raster calculator algorithm. The result of this is the production of a flood map (Fig. 7).

$$Flood\ risk\ map =$$

$$Slope\ + Elevation\ + Drainage\ distance\ + Wetnes$$

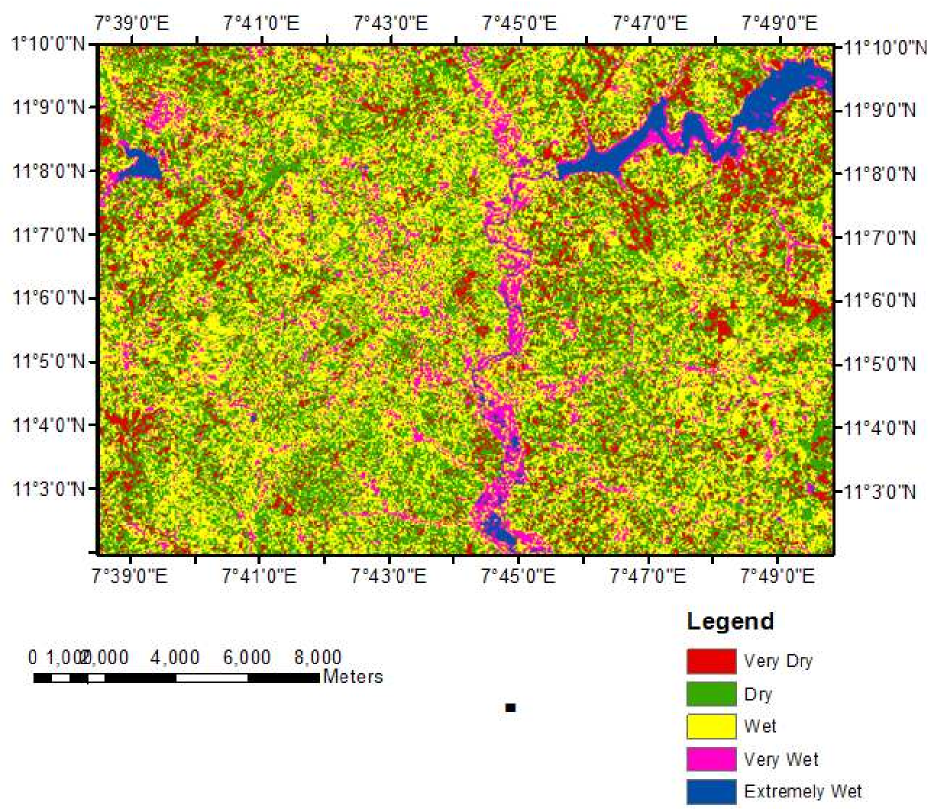

Fig. 6. Surface wetness map for study area

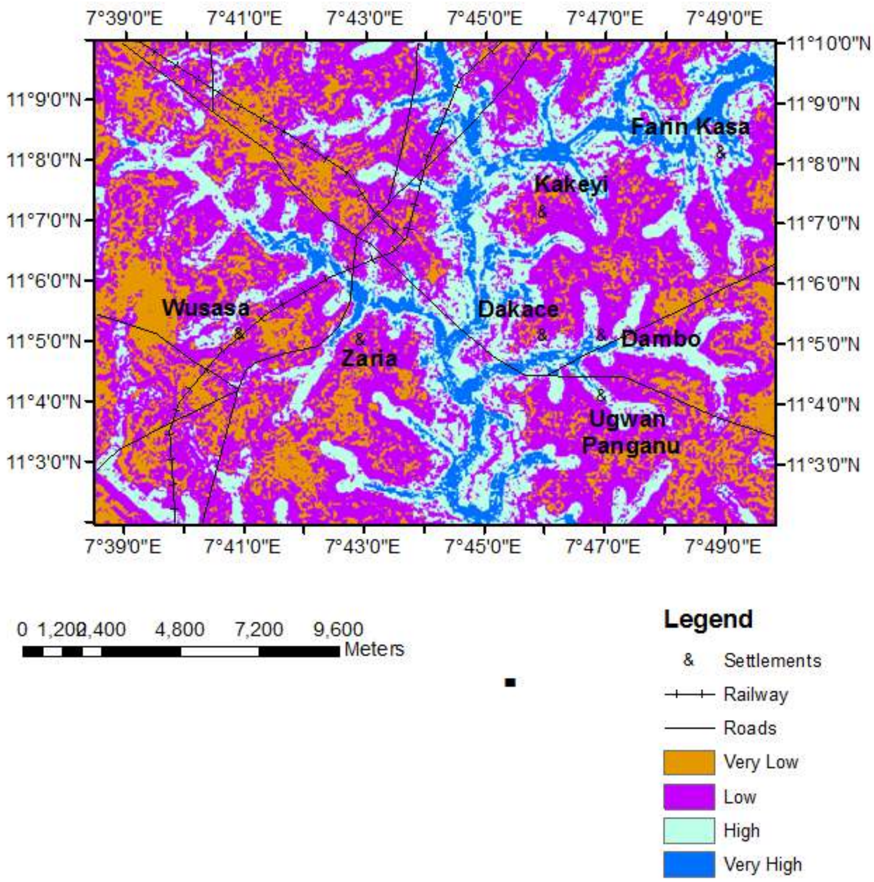

Fig. 7. The flood risk map obtained for the study area

3. RESULTS AND DISCUSSION

Application of GIS and remote sensing in identifying flood prone areas have produced fascinated results. In order to maintain a high degree of accuracy, the consistency ratio which measures the reflection of one judgment for calculated weight was kept below 0.1. Flood hazard map reveals areas having very low risk of flooding 28.3% of the total area and covers some 86.88 Km^2. Areas with low flood risk account for 29.5% of the study area and covers an areas extend of 90.565 Km^2. Areas with high risk accounted for 32.1% of the study area and has an area extend of 98.547 Km^2. Areas identified as having very high flood risk potential account for 10% of the study area and has an area extend of 31.007 Km^2. Flood risk map also reveals flood risk zones are common in the West, South West, West Central. North West and North Central. Areas of low flood risk are spread throughout the study area but uncommon around the Central and North Eastern part of the study area. Areas of high and very high floods are observed around the central and North Eastern part of the study area.

4. CONCLUSION

This study have revealed the significance of remote sensing and GIS in flood mapping. Flood maps for any area are invaluable in decision making with regards to environmental planning. Such a map will inform appropriate decision makers where extra efforts is required to prevent flood hazards. From the result it was observed that high risk to Very High risk zones constitute 42.1%. This zone which is highly susceptible to flood occurs in the central and South Eastern part of the study area. This reveals that an appreciable part of Zaria and Environs can be subjected to flooding, thus necessary precaution should be applied to such zones. Low flood prone areas are common around the West, South West, West Central, North West and North Central part of the study area. These zones can be deem safe with regards to flooding.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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