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Reaserch Article

Geomorphic Assessment of Flood Hazard within the Urban Area of Chanchaga Local Government Area, Minna, NIGERIA

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Abstract

Pairwise comparison, Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) has been recently used to assess flood hazard. It has been used to carry out Multi-Criteria Analysis (MCA) of various geomorphic factors by assigning weight based on the presumed impact of each factors on flooding. This study considered six factors which include; Slope, curvature, landcover, elevation, distance from river and soil using Rafinsenyi river in Chanchaga Local Government area, Minna-Nigeria, as study area. Review of literatures showed that methods of assigning weight are hypothetical and inconsistent, this research thus take input from researchers in field of hydraulics, hydrology and disaster management. The weight with 0.029 as the least consistency ratio was used. Data used include; DGPS data, Satellite Images, Digital Soil Data. Landcover Maps, Digital Elevation Models (DEM), Soil Maps and Profile Curvature maps were generated. Weighted overlay operation was carried out in ArcGIS to produce a Flood Risk Map. Livisol (Loam) soil reveals why farmers and traders indiscriminately settle along floodplain. 6 of the 20 hectares of study area lies between 216 and 220 metres above mean sea level, putting residential building at high risk of flooding.

Keywords: Geomorphic factor, flood hazard, analytical hierarchy process, digital elevation model, soil type and land cover.

Introduction

Flood was merely geophysical event, alongside with volcanic eruption, earthquakes and landslides among others. They became natural disaster and hazard as soon as Man begins to explore and influence the environment (Kwabella 2011). The transformations activities include social division of work (Ajin et al., 2013), production related activities, economic and political system among others. These transformation and influence by men, served as a basis upon which natural disaster and hazard events operate (Kwabella, 2011). Apart from the influence of man, rainfall is also an important factor that contributes to flooding (Kim and Kim, 2014). Natural hazards are natural conditions and elements that act hazardous to human being and their environment in a defined space and time (Kwabella, 2011).

Flooding is considered to be one of the most common disasters in the world that affects not only the environment but also the economy (Merz et al. 2010). Nigeria as one of the developing countries in the world is not left out of this menace of flooding. IFRC (2020) reported that, 22 states of the six geopolitical zones in Nigeria are affected by flooding yearly; it has weakened various infrastructure, roads properties and lives. Some records of incidents are; North West (4 state), North Central (4 states), North East (4 state), South East (4 states), South-South (3 states) and South West (3 state). It is also important that Northern states are most frequently plagued with this flooding event, with an approximation of 55 percent of occurrence. They also reported that a damage estimates worth N10bn have been incurred between September to October 2020, torrential rainfall, river floods and flash floods have cumulatively impacted 192,594 people across Nigeria.
Natural vulnerability occurs when natural features are exposed to the influence of the dangers attached to geophysical event while human vulnerability describe human system and their exposure to danger (Olayinka and Irivbogbe, 2017; Direk et al., 2012; Menteş, et al., 2019). The point of intersection between these types of vulnerability is termed Natural disaster (International Decade for Natural Disaster Reduction 1992). Urban areas only become disaster prone, when uncontrolled development overlap with the zone of natural vulnerability, most especially the influence of low-income earners (Pedersen et al., 2012).

Flood risk management is thus an important factor in curbing the effects and dangers associated with flooding, it gives early warning (Tehrany et al., 2013), quick response (Nerantzis et al., 2015) and reduce the impact of such event. In order to manage flood, assessment is thus an important factor to be considered. Flood risk assessment have been classified by various researches into two main section; assessment and mitigation (Schanze et al., 2006), Hazard evaluation and Damage-

Loss assessment (Dottori et al., 2016). Both describe the assessment of hazard itself, its impact and implication.

Flood risk assessment focus on four main components; Flood Hazard, Exposure, Vulnerability and performance. These four components are basis upon which various flood risk assessment approaches are based on. The assessment is defined and based on the magnitudes of probabilities attached to various conditions that lead to flooding. It also depends on various data and factors such as; meteorological (rainfall data), hydrological (runoff data), socioeconomic factor, hydrometeorological parameter of the water body in the location of interest (Oriola and Chibuike, 2016).

Flood mapping utilizes this data to produces charts and maps that help decision makers to visualize flood risk area more priorities of management and prevention could be placed (Ajin et al., 2013). Flood risk and hazard maps aids assessment process and help in technical decisions (Bhatt et al., 2014). This has been used extensively in the field of hydraulics and hydrology for flood prediction (Myronidis et al., 2009). Various natural and anthropogenic events that influence flooding have been the core branches in the study of flood and its events.

Natural events such rainfall, has been examined by various researches in relation to flooding. Chen (2011) examine the overwhelming drainage capacity for rainfall. (Ologunorisa 2006; Daffi et al., 2014) confirm this that rainfall variability has made the existing drainage system of less effect to tackle the incident of flooding, (Mohammed and Kawu, 2014) reveals that this has led to the annual rainstorm damage experienced in urban area , (Billi et al., 2015; Dalil et al., 2015) stated that physical development along drainage network pose dangers to such development during high rainfall, which may in turn lead to flooding. Researches has also concentrated on geomorphic factors as they influence flooding

The earth surface response to natural hazard depends on the magnitude and frequency of the event, the nature and type of surface materials involved and the extent or area involved. All these factors are describing as geomorphic concept related to natural hazard. Geomorphic process and features have great effects on urban development and management, it is therefore an important object of study (Abah, 2013). Daffi et al. (2016) stated urban geomorphology combines ambient geology, landforms, and geomorphic processes with an evaluation of their impacts on flooding due to urbanization. The magnitude and frequency of flooding event has been further studied as a probability event.

Flood risk is commonly represented with a damage–exceedance probability function. Various methods available for flood vulnerability assessment thus depend on this function to operate. NAP (2015) highlight the various approaches for flood risk assessment in flood plain, they include; NFIP hydrologic method, USACE method, catastrophe models, comprehensive risk assessment and Multi Criteria Analysis Assessment. The first four of the flood risk assessment approaches listed address the main components of risk (i.e., flood hazard, the performance of flood protection measures, exposure, and vulnerability) based on hydrologic and hydraulic models that represent the watershed, channel, and tidal behavior for the entire range of possible events.

Another approach is the methodology developed by (Dottori et al., 2016), which is based on an index in GIS called Flood Intensity Index (FII), which can be considered as a trade-off between morphometric indexes and physically based two dimensional (2D) hydraulic models, the flood indexes are used to generate areal vulnerability curves for assessment. It has an advantage of providing valuable information with limited resources, since probabilities are assigned with computer algorithms and curves. Many factors contribute to flooding, approaches that can combine this effect in its analysis without affecting the probability, magnitude and frequency of each factors, has been the basis for the development of Multi-Criteria Analysis (MCA) as suggested by Njoku et al., (2013), he describe it as integrated data analysis approach. Complex and Multiple criteria affecting flooding can thus be combine to make decision in flood assessment and management. This approach was developed by Saaty (1980) It uses hierarchical framework, which rate factors based on their relative importance. Unavailability or lack of experimental results has promoted the use of this approach in earth science, economy and social science among others (Njoku et al., 2013).

Multicriteria analysis (MCA) assigned relative weight to factors based on scale of importance highlighted in (Saaty 1980), these weight are describe in term of relationship between a factor and another, ranging from 1-9.The most popular techniques for the estimation of the relative weight of each factor are the direct method of rating (Zangemeister 1971) and the pairwise comparison (Koelle, 1975). The first one grades each factor separately and adds all grades into a constant sum (e.g. 100), while the second one relies on the comparison of factors in pairs and the expression of results into a range scale of a constant sum.

Gatzojannis et al. (2001) used the direct method of rating, in order to study the protective role of forests against torrential phenomena. Many researchers used pairwise comparison, within analytic hierarchy process method (AHP) and geographical information systems (GIS) to assess flood hazard (Sinha et al., 2008; Meyer et al., 2009; Chen et al., 2011).

Comparative studies regarding the aforementioned methods revealed that the pairwise comparison leads to the most reliable results (Grozavu et al., 2011; Stefanos et al., 2013). Furthermore, recent researchers (Scheuer et al., 2011; Wang et al., 2011) combined the analytic hierarchy process with fuzzy logic and genetic algorithms in order to incorporate the possible changes (climate change, land use change) over years into the assessment of flood hazard and management of water resources.

Pairwise comparison generates a matrix from these combinations of weights, and tests the validity of this matrix through the use of consistency index and consistency ratio tools (Saaty, 1980). This validity leads to the resolution of percentage influence of each factors, which is a criteria used to carry out weighted overlay operation in GIS for the production of Flood risk map. This process is described as Analytic Hierarchy Process (AHP).

Analytic Hierarchy Process (AHP) developed by Saaty (1980) is one of the best known and most widely used MCA approaches (Orencio and Fujii 2013; Yahaya et al., 2010). AHP is used to solve a broad range of multi-criteria decision-making problems, with the pairwise comparison matrix calculating the weights for each criterion considered (Orencio and Fuji 2013; Pourghasemi et al., 2014; Olayinka and Irivbogbe, 2017; Parry, et al., 2018; Ulukavak and Miman, 2021). AHP assumes complete aggregation among several criteria and develops a linear additive model. The uniqueness of applying AHP in different studies helps in modelling situations of uncertainty without losing subjectivity and objectivity of any evaluation measure.

Recently, considerable attention has been given to the use of AHP in natural hazard (earthquake and flood) assessment but more in flood management in various studies: (Yahaya et al., 2010; Cozannet et al., 2013; Orencio and Fujii 2013; Saley et al., 2013; Chakraborty and Joshi 2014; Pourghasemi et al., 2014; Papaioannou et al., 2015; Nejad et al., 2015; Olayinka and Irivbogbe 2017). It has been shown from these series of literatures that AHP has the ability to assess and map flood risk with good accuracy.

Various flood risk models have been reviewed and they have great contributions to flood risk assessment, however there are some identified gaps in these models. Models have been inconsistent about assigning relative importance to flood risk modelling factors (Dottori et al., 2016) based on the various literatures, independent assignment of weight to such factors may not be sufficient to make decision regarding factors affecting flooding.

Another significant research gap identified by this study is that recent scientific work undertaken in Barki-Sale, Minna, Niger State concentrated on rainfall variability (Ologunorisa 2006; Daffi et al., 2014) , annual rainstorm damage (Mohammed and Kawu,l 2014), physical development along drainage network(Billi et al., 2015; Dalil et al., 2015)during past and current condition as flood risk drivers within the communes of Barki-Sale. This is a piece-meal approach and does not provide a solution to the problem of flood occurrence within the entire area. Other studies in the area did not directly focus on flood but pointed out the inefficiency of the drainage network and impervious area which are part of the main drivers of floods. However, these studies are fragmented and did not consider the entire district and multi criteria as input to link climate change and flood occurrence, no studies have yet been undertaken to evaluate and map flood risk at Barki-Sale level.

More recently in Minna, Niger State, populations have experienced increasingly important phenomena of floods, with its effects such as death, damage to property and population exodus. Heavy rainfall is the main natural hazard which causes loss of many lives; destruction of infrastructures, and the displacement of people during the rainy season in the study area. However, the use of multi-criteria evaluation approach to flood risk assessment and mapping in the study area is still rare. Flood risk occurrence is a combination of natural and anthropogenic factors, which means that there is the need for knowledge about spatial extent of flooding areas, using multi data as drivers becomes a potential source for more reliable flood management and mitigation. Review of literature show that researcher took into account only the natural factors at the estimation of flood hazard. However, several studies about the causes and the mechanism of flood phenomena concluded that floods could have been avoided if no geomorphic assessment of flood interventions existed within stream beds (Marchi et al., 2010; Olayinka and Irivbogbe, 2016).

Regulation and control of landuse has serious impact on landform dynamics and disaster management in the study area. The purpose of the current study is to carry out geomorphic assessment of flood hazard of Part of Barkin-Sale, Chanchaga Local Government Area, Minna, Niger State, and Nigeria in order to prioritize management and protection actions. Assessment process of flood risk was conducted under hazard and vulnerability concepts within analytic hierarchy process (AHP) framework.

Materials and methods

Factors of flooding

The identification of the flood genesis factors is the most important step at the assessment of flood hazard. The inclusion of the factors should be done within a framework ensuring that the whole problem is encompassed. Moreover, the set of factors should be kept to a minimum so as to reduce the complexity of the evaluation process. After extensive literature review, the factors that determine the flood hazard were selected according to the conditions and the available data in the study area. The factors that were used in the current research include; Land uses, Geological Subsoil, Mean slope of watershed, Curvature and Elevation.

Analytical hierarchy process

Analytical hierarchy process (AHP) is a multicriteria decision-making technique which provides a systematic approach for assessing and integrating the impacts of various factors, involving several levels of dependent or independent qualitative as well as quantitative information (Saaty 1977, 1990). AHP makes the assessment of the contribution of each factor easier and overcomes problems such as overlapping and interrelation between factors.

The most common methodology for performing comparisons is the Saaty's (1980) comparative scale. According to this method, the comparative scale consists of integer numbers from 1 to 9, where 1 means that the factors are equally important and 9, that a factor is extremely more important than another. The comparison process was done for the chosen factors, and the relative weight of each factor was assessed. Additionally, this software computes the consistency ratio derived from the comparisons among factors. In order to check the discordances between the pairwise comparisons and the reliability of the obtained weights, the consistency ratio (CR)R) must be computed. In AHP, the consistency is used to build a matrix and is expressed by a consistency ratio, which must be < 0.10 as to be accepted.

Study area

The study area is located in Chanchaga local government area, Minna, Niger State, Nigeria and has an area of 72.0km2. Chanchaga local government area comprises of seven (7) wards namely; Nassarawa, Limawa, Sabon-Gari, Makera, Kwangila, Tundun-wada and Kpakungu respectively. Barkin Sale is part of the communities in Kpakungu ward of Chanchaga local government area in. Figure 1 shows the map of the study area and the satellite imagery of the area as obtained from the Google Earth. The study area lies between latitude 090 35' 24" N and 090 35' 43" N and longitude 060 33' 00" E, and 060 33' 02" E. The area is characterized as lowland with an average altitude of 216 m (maximum 231 m), an average mean slope of the watershed 30% and an average main stream slope 5 %. As for the ground, the soil type of the study area was found to belong to the soil mapping unit symbol of LP6 with record number of 1537 (FAO, 2019). This soil type was later identified to be known as Luvisol with high contents of loam which is the main reason for farming and trading in the region. The dominant bedrocks are sedimentary rocks, especially marls.

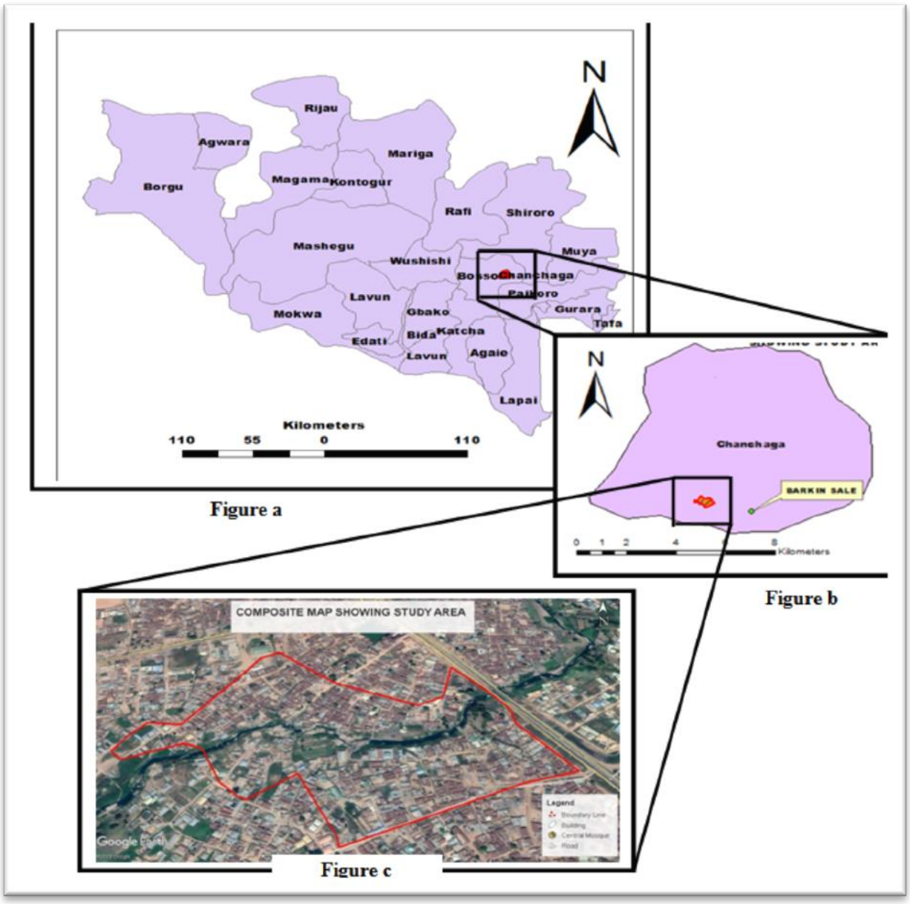


Fig. 1: (a) Map of Niger State showing various Local Government (b) Map of Chanchaga Local Government (c) Composite Map of the Study area.

Methods

This section highlights the method of data used in generating the flood risk map and flood vulnerability assessment. The coordinates of selected points in the study area were acquired using a Differential Global Positioning System (GPS) receiver. Other data used for the study were acquired through secondary means, these include digital soil map of the world downloaded from the Food and Agricultural Organization (FOA) of the United Nation website, Landsat imagery of Niger State downloaded from United State Geological Survey website-earth explorer, Google Earth imagery of the study area for reconnaissance survey and literature and other print materials.

The GPS data acquired for the entire study was imported into ArcGIS environment for DEM creation. A DEM is a bare-earth raster grid referenced to a vertical datum. The DEM of the study area was needed in order to extract other parameters of input such as slope, curvature and elevation for terrain analysis of flood.

Slope elevation and curvature are among the parameters of input in terrain analysis for flood vulnerability of the study area. The slope elevation and curvature were extracted from the DEM of the study area that had been created from the point data observed on the field as well as the elevation.

The Euclidean distance to the river found within the study area was calculated to determine the allowable distance from the river to settlements. 50 metre maximum distance was assigned as the buffer zone (Oriola and Chibuike 2016). The process was carried out using the river shapefile on ArcMap environment. The result was also reclassified into five classes.

The acquired Google earth imagery was also georeferenced using five visible points in the study area, essential features such boundary settlements and rivers was digitized using the ArcGIS software. Table 1 describes the data acquired and used for the study work.

Table 1: Data and data sources of the study

S/no.	Data	Source	Type	Relevance	Date
1	Literature	Journals, publications, research thesis, and internet sources	Secondary	To reveal past work done on similar subject matter, methods adopted and results derived.	***
2	Satellite Imagery	Google Earth,	Secondary	For preliminary identification and location of study area	2019
3	Landuse map	Field survey and Landsat Imagery	Primary	Identification of various land uses within the study area and for the purpose of analyses	2019
4	Coordinates and attributes	Field survey (use of HI-Target V30 DGPS)	Primary	Spatially acquisition the coordinates of the points covering the study area	2019
5	DEM	X, Y, Z coordinates of the study area	Primary	Extraction of the terrain parameters for analysis	2019
6	Digital soil data of the world.	Food and Agricultural Organisation (FAO) of the United Nations	secondary	Soil map preparation for the study area to ascertain the type of soil and it influence in flooding.	2003

Table 2: Pairwise comparison matrix

Factor (Flood Indicator)	Slope	Curvature	Landcover	Elevation	Distance to river	Soil
Slope	1	2	5	4	6	6
Curvature	½	1	3	4	5	4
Landcover	1/5	1/3	1	3	2	1
Elevation	1/4	1/4	1/3	1	1	2
Distance to river	1/6	1/5	½	1	1	1
Soil	1/6	1/4	1	½	1	1

Land cover map creation

The land cover map created from the satellite imagery covering Niger State and the study area was clipped from the result. The classification was carried out on Erdas Imagine 2014 software. The process involved pre-processing of the imagery to remove cloud cover found on the satellite imagery.

After the pre-processing operation, the next operation was the training site for classification of the Landsat imagery to obtain the land cover map of the study area. To attain high accuracy of the training samples of the supervised classification, the operation was carried out online in order to connect the software with google earth for proper and accurate identification of features on the training site.

Accuracy assessment was performed for proper validation of the image classification process using Google Earth imagery and the coordinates of points in the study area acquired on the field. Finally, the image was saved and imported in ArcMap for further analysis to be carried out.

Soil type preparation

Soil type of an area plays an important role in the permeability or otherwise of surface water. The soil type of the study area was considered as one of the parameters of key input in the flood analysis. The digital soil map of the world was downloaded from the Food and Agriculture Organization (FOA) of the United Nations website. The data was imported to ArcMap where the soil map of Nigeria, Niger State and Bosso and finally Chanchaga Local Government Area respectively were extracted and clipped for analysis. From the information derived from the soil map preparation process, the soil type of the study area was found to belong to the soil mapping unit symbol of LP6 with record number of 1537. This soil type was later identified to be known as Luvisol.

Weighted overlay operation

In order to generate a flood risk map, various factors that affects flooding such as slope, curvature, land cover, elevation, distance to river and soil were given weight based on administered questionnaires to researchers in the field of hydrology and hydraulics, their hypothetical weight were used to evaluate their consistency index with consistency ratio was tested using the pairwise comparison matrix made available by the Analytic Hierarchy Process(AHP). The weight allocation with the smallest consistency ratio was used and shown the process is described below.

Developing the single pairwise comparison matrix for the criteria

Table 2 shows the various weights assigned to the identified factors that influence flood and its risk, six of these parameters were used to develop the matrix for the comparison.

Multiplying vector rows and normalizing the matrices

Table 3 shows the multiplication of row vectors and the 'nth' root function where $n = 6$= 6or six parameters. The criteria weights shown Table 4, were obtained by normalizing the acquired multiplication of row vectors by evaluating the 6th root of each criteria, and dividing it by their summation (8.048), since summation of the criteria weight must be equal to 1.

Table 3: Determination of the 6th root for matrices

Factor (Flood Indicator)	Slope	Curvature	Landcover	Elevation	Distance to river	Soil	Multiplication of rows	6th root of product
Slope	1.000	2.000	5.000	4.000	6.000	6.000	1440	3.360
Curvature	0.500	1.000	3.000	4.000	5.000	4.000	120	2.220
Landcover	0.200	0.333	1.000	3.000	2.000	1.000	0.4	0.860
Elevation	0.250	0.250	0.333	1.000	1.000	2.000	0.04	0.590
Distance to river	0.167	0.200	0.500	**1**.000	1.000	1.000	0.02	0.510
Soil	0.167	0.250	1.000	0.500	1.000	1.000	0.02	0.520

Table 4: Obtaining the criteria weight

Factor (Flood Indicator)	Criteria Weight (w)	Sum PW	Sum PW * (w)
Slope	0.420	2.280	0.950
Curvature	0.280	4.030	1.110
Landcover	0.110	10.830	1.150
Elevation	0.070	13.50	0.990
Distance to river	0.060	16.100	1.000
Soil	0.070	15.000	0.980
Total	1	61.65	6.180

Table 5: Values of the Random Index RI for Small Problems

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Table 6: Determining the best consistency ratio for each assigned weight

S/N	CASES	Consistency index	Consistency ratio
1	A	0.065	0.052
2	B	0.036	0.029
3	C	0.089	0.072

Table 7: Determining Percentage Influence for Each Indicator

Factor (Flood Indicator)	Criteria Weight (w)	Percentage Influence (%)
Slope	0.42	42
Curvature	0.28	28
Landcover	0.11	11
Elevation	0.07	7
Distance to river	0.06	6
Soil	0.07	7
Total	1	100

Determination of consistency index

The consistency ratio was resolved using equation (3), where CI is Consistency Index, *x*- Sum of average rows, *n* - order of matrix

$CI = 0.0$= 0.0

Checking for consistency ratio

RI = Random Index, for six (6) factors considered in the study, the RI is 1.24. Table 5 shows the order of matrix and their respective random index for problems $(n \leq 10)$ ≤ 10) developed by (Saaty, 1990).
Hence, the consistency ratio is given in equation 2 as follows:

$CR = 0$= 0290

This procedure was repeated for the subsequent weight assigned by various research in the field of hydraulic and hydrology, as shown in table 6.

All calculated consistency ratio (CR)R) shows a value less than 0.1, the Consistency ratio $(CR$R 0.0290 is thus acceptable and that the pairwise comparison alongside with the respective weight obtained are consistent and can be used for decision in flood vulnerability map. The obtained weight was thus converted to percentage influence in Table 7, to be used for weighted overlay operation in Geographical Information System (GIS).

The percentage influence table shows that Slope as a factor, which describes the rate of change in elevation with distance is of greater influence in the incident of flooding. Area with steep slope has higher tendency of getting flooded, than areas of gentle slope. Exposed land cover is liable to flooding than landcover characterized with vegetation. Soil type also have influence on the carrying capacity of the ground, the type of soil determines whether or not an area will be water logged or not.

Results and discussion

Figure 2 shows the result of the reclassified slope map of the study area, it was classified into five categories as Very low (23.8%), Low (37.28%), Moderate (35.44%), High (0.60%) and Very High (2.88%) respectively. This shows that a larger part of the entire study area will be flooded during high flood due to steeply slope. The higher areas with steeper slope are equally at considerable risk as velocity of the flood water will be high and any man-made structure along these routes will likely be wept.

Figures 3a and 3b show the curvature and the profile curvature of the study area. Curvature is one of the flood-influencing factors. The profile curvature is parallel to the slope and indicates the direction of maximum slope. It affects the acceleration and deceleration of flow across the surface. A negative value of 34.94 indicates that the surface of the study area is upwardly convex at that cell and flow will be decelerated. A positive profile indicates that the surface is upwardly concave at that cell and the flow will be accelerated at that point.

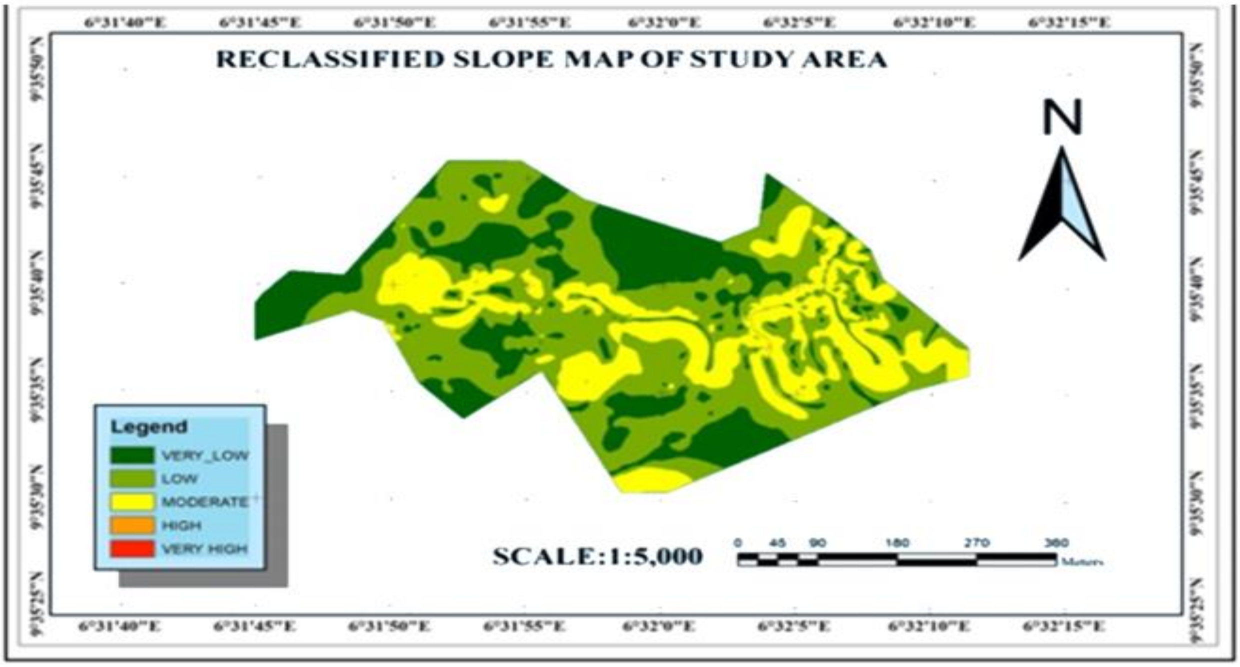


Fig. 2: Reclassified slope map of study area

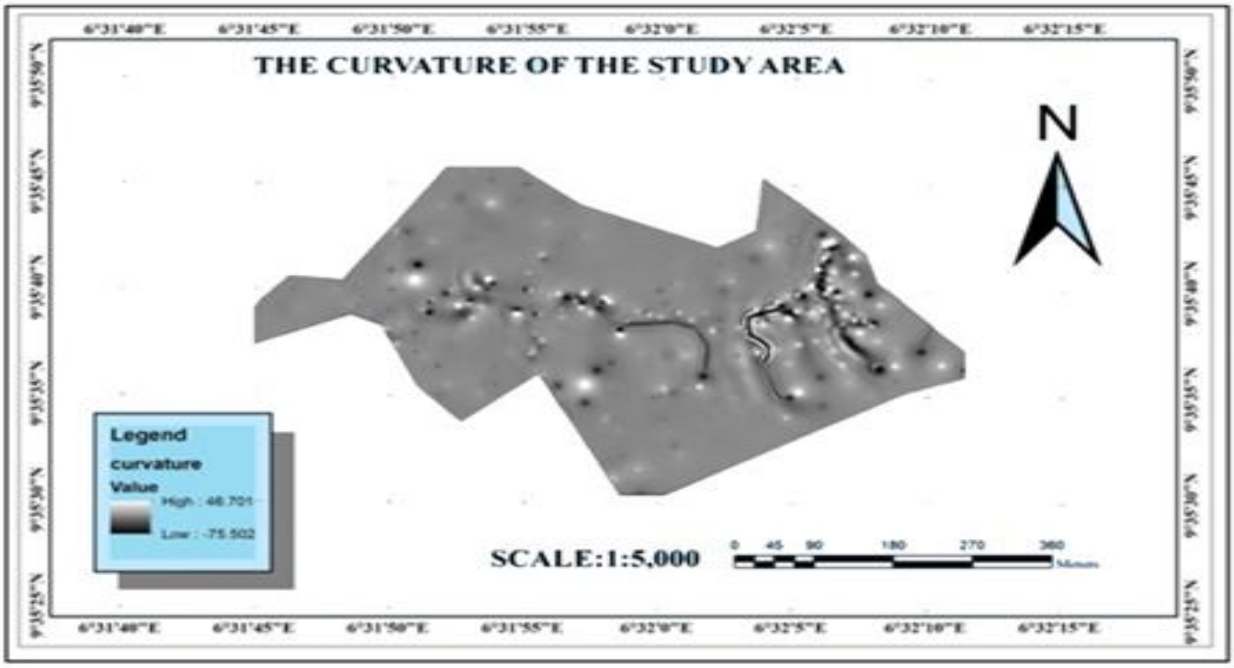
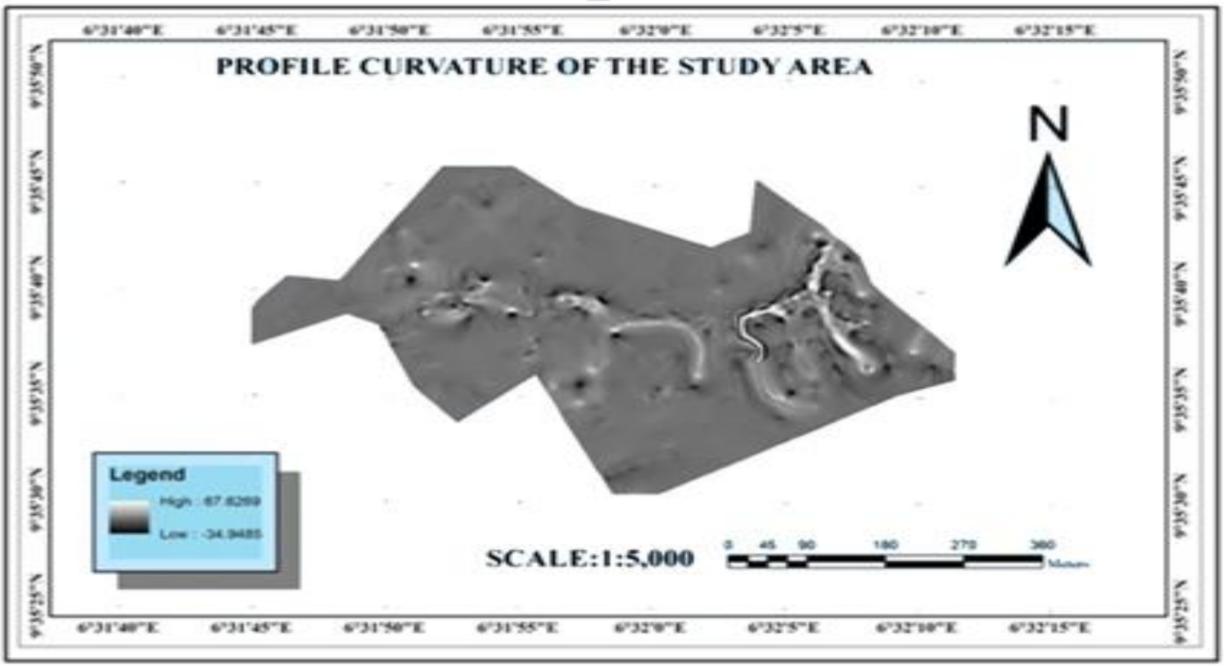


Figure 3a: Curvature map of study area



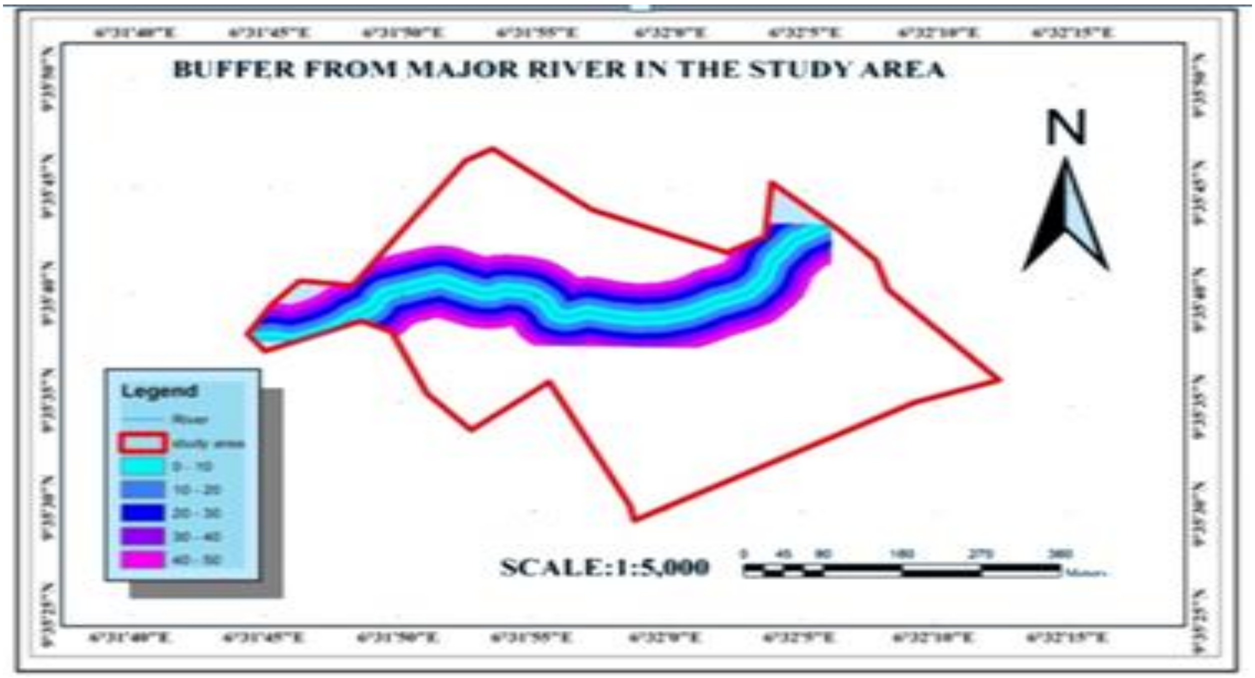


Figure 4: Buffer from Rafinseyi river in the study area

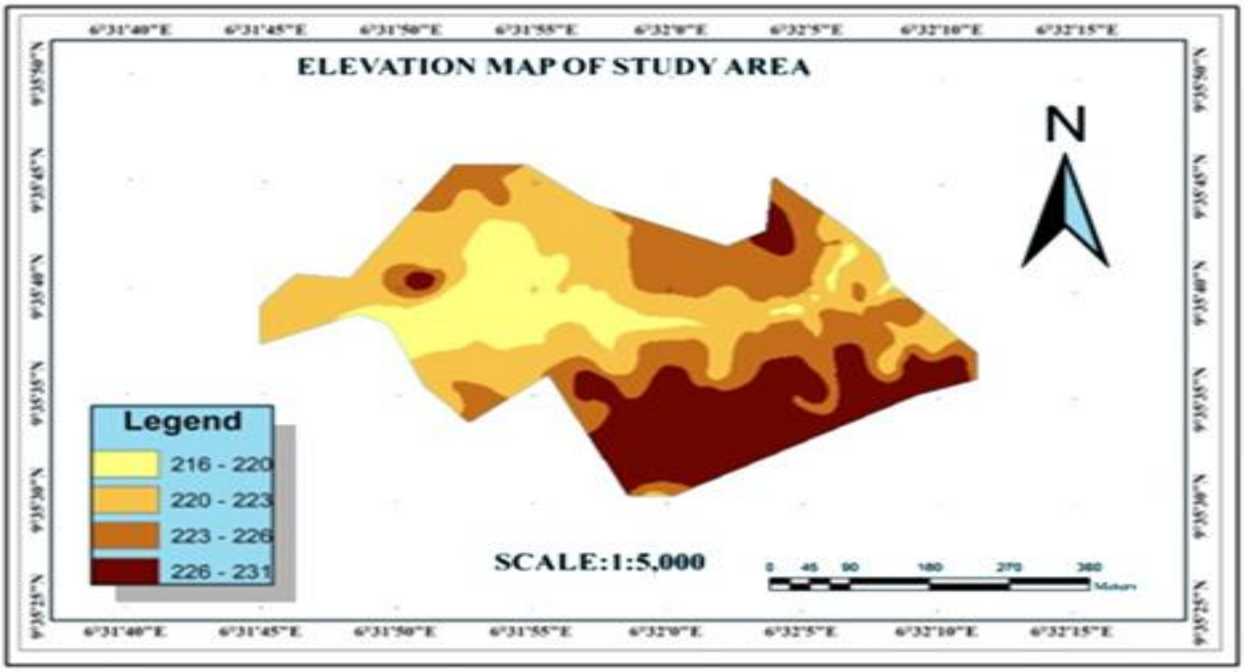


Figure 5: Elevation map of study area

Figure 4 shows the buffer zone or distance from Rafinsenyi River in the study area. The width of the river is approximately 20 meters indicated as 0 to 20 in the legend. The maximum covering distance was assigned to the buffer zone from the river as shown in the figure under review. This implies that buildings within this maximum covering range of the river are at high risk of being flooded if there is a heavy downpour and the river overflows its bank. The buildings within the 20 to 30 meters range are very much at the risk of being inundated should the river overflow its bank. Other structures within the remaining ranges are moderately at the risk of being covered by flood in the case of any emergency. From the satellite imagery of the study area gotten from Google Earth and from primary data collection, it was observed that a lot of buildings are sited within the maximum covering range of the river. As such, these areas are very much at risk of flooding.

Figure 5 shows the elevation map of the study area. The elevation of the study area ranges between 216 to 231 metres. Elevation is an important flood-inducing factor. The portions identified as low or flat elevations are between 216 to 223 metres respectively and are considered to be inundated during flood as those areas are likely to collect more water and not being capable of letting it out. Structures sitting within these low elevation areas are to be mostly affected in any flood occurrence.

Figure 6 shows the land cover map of the study area. The land cover shows that the area is a built-up area with sparse bare ground and pockets of river tributaries. With buildings clustered all over the study area even along natural drainage systems and the bare ground being impervious, there is every likelihood that those areas are at the risk of being flooded. The result of the classification somehow is not aesthetically pleasing due to the fact that the study area is considerably small compared with the large satellite imagery covering the entire Niger State and part of Kaduna State. The implication is that the 30-metre resolution obtainable from Landsat imagery with respect to the study area will be too blurred.

The soil type covering the entire Chanchaga Local Government Area where the study area is located was identified as Plinthic Luvisols from the information provided by FAO soil inventory of the world having a mapping unit name of Lp6 and a record number of 1537. This type of soil is typically characterised by a surface accumulation of humus overlying an extensively leached layer that is nearly without clay. The soil has high nutrient content and suitable for a wide range of agricultural purposes from grains to orchards. Luvisols form on flat or gently sloping landscapes. The description of this type of soil makes it a flood-contributing factor as it is suitable for agriculture and forms on flat landscape.

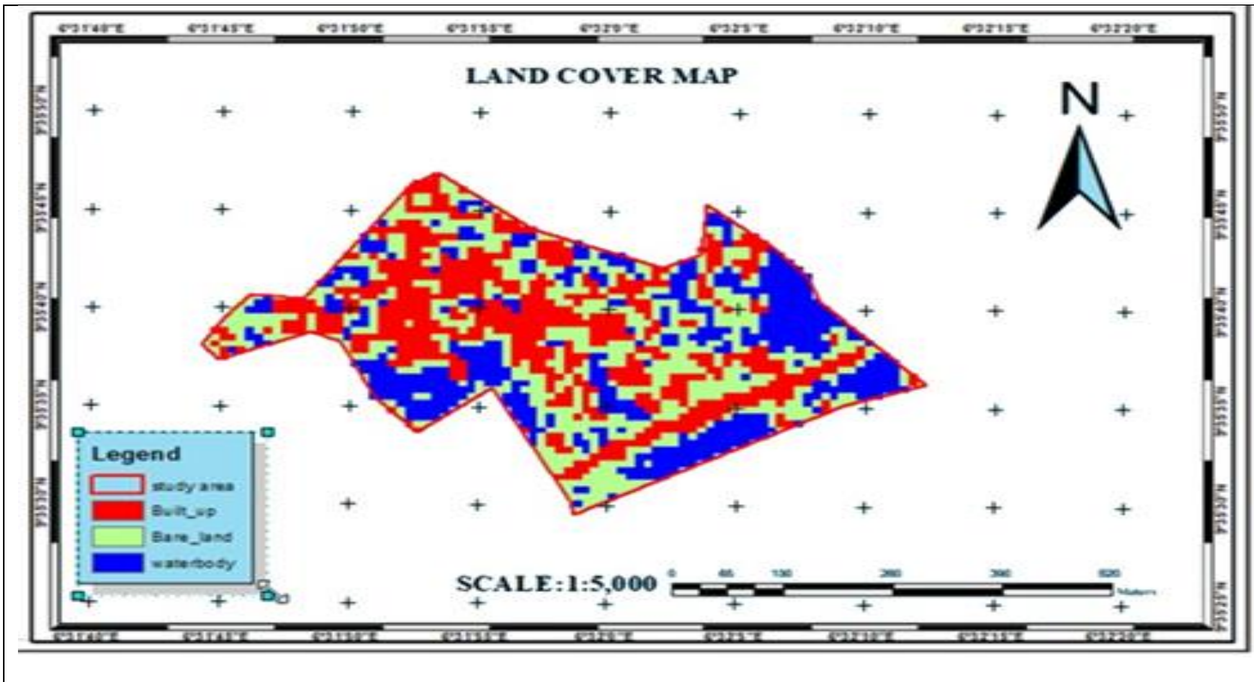


Figure 6: Land cover map of study area

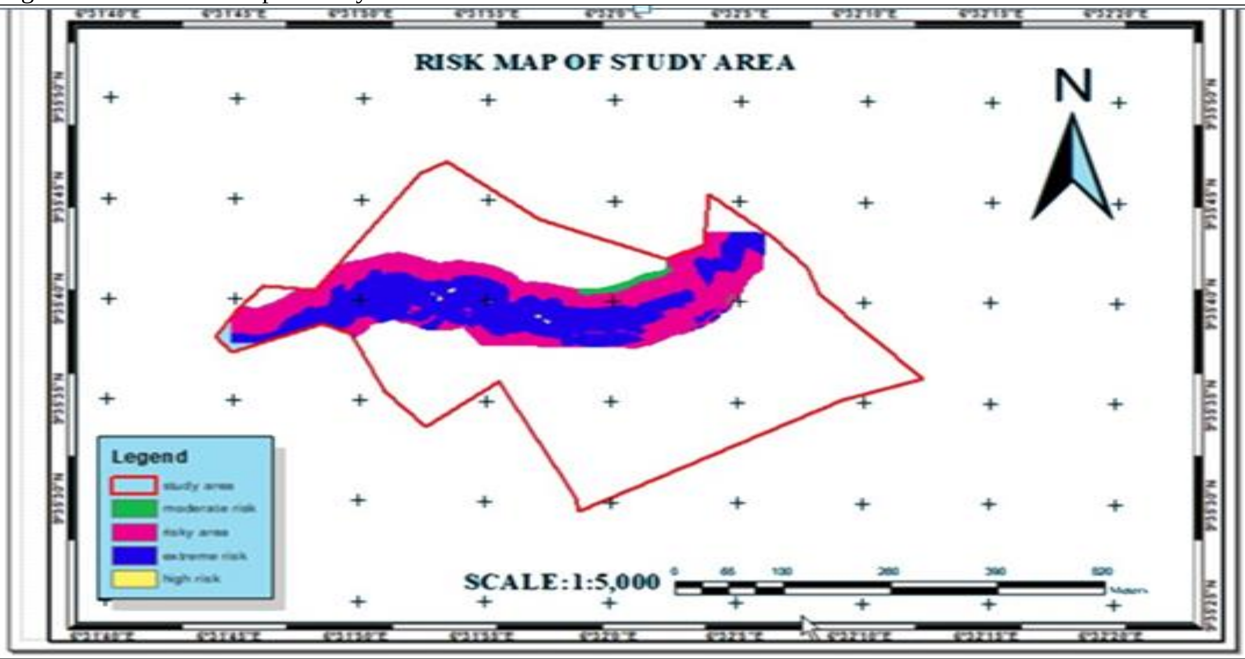


Figure 7: Risk map of study area

Conclusion

The study examines landform of geomorphic parameters that affects the flooding incident in Barkn Sale area of Chanchaga Local Government Area, Minna Niger State. Urbanization and their corresponding vulnerability are important factors in flood management. It is also important that geomorphic factors are considered in flood hazard mapping. Information generated for this study were extracted from DEM, LandUse and soil data, the combination of ArcGIS processing with geomorphic studies revealed some basic physical-geographical characteristics of Barki-Sale and its immediate environs that have a direct bearing on floods. Analytical Hierarchy Process (AHP) and GIS analyses have demonstrated that it is possible to effectively produce flood risk maps by integrating six selected factors that influence flooding. The factors include; slope, curvature, LandUse, elevation, distance to river and soil types. Pairwise comparison shows that slope and curvature as factors influencing flood, have higher percentage of influence 37 and 33 respectively while distance to river having the least influence. The weight (percentage of influence) obtained were integrated into ArcGIS using weighted overlay tool alongside with DEM generated from coordinates acquired by DGPS observation, thereby producing flood risk map. The map reveals negative elevation in curvature and a core centre of flood risk towards the North-West part of the study are with characteristic properties of having a higher percent of low elevation, direction of river flow, and built up area from the landcover map. Analysis and concept used in this study are limited to the scope of the study area, a large-scale analysis is further suggested to enhance it usability for country-wide application.

Suggestions

It is suggested that the Indiscriminate siting of residential buildings along natural and artificial water drainage systems and the unplanned development should be curbed as they are strong indicators of the vulnerability of the study area to flooding. The increasing population should be educated against indiscriminate habitation along floodplain as the habitation of the floodplains of the Rafinsenyi river by the locals which is the first point of contact should the river overflow its bank, foretells danger too. Public enlightenment and awareness on early flood disaster warnings should be done. The authors further recommend the use of hydraulic and or hydrological methods of flood risk mapping in subsequent research works on flood.

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