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Assessment of the Digital Terrain Models for Flood Planning and Disaster Management in Minna, Niger State

Dogara N. Baba, Muhammed O. Nanahauwa, Pius O. Ibrahim, Muhammad A. Yaman
Department of Surveying and Geoinformatics, Federal University of Technology, Minna, Niger State

Abstract
The occurrence of floods and their effects on human existence as well as the general environment has unfortunately been on the increase owing to human-induced climate change and poor infrastructural location. Hence, the aim of this project was to assessed and modeled the digital terrain models of Minna and its environs using geographical information system tools. The data used are from open source and ground observation using handheld GPS. A geospatial technique was used to map and analyze the study area's hydrological characteristics. A map showing the vulnerable areas was produced using buffering and indicating the risk zone areas. Additionally, the Digital Elevation Model (DEM), Land use land cover map, and the geomorphological map were developed representing the physical characteristics of the study areas. The research findings show that the lack of a proper drainage system is a contributing factor to flooding in Minna. Increased rural-urban migration and building on water waterways are additional factors. The study recommended that proper drainage and government building regulations should be followed to reduce the amount of drainage blockage.

Keywords: Flood, Vulnerable, Riverbanks, Assessment.

1. Introduction

Natural disaster is one of the most serious problems facing all countries of the world. Hence, a remarkable global trend towards growing deaths, casualties, and economic losses resulting from disasters has been seen in recent years are associated with flooding (Alrehaili *et al*., 2022). Flooding may occur when water from a lake, river, dam, or rainfall overflows beyond the natural boundaries of dry land which causes some negative effects on life and properties (Onuigbo, 2017). The negative effects which are debilitating and multifaceted, ranging from the destruction of the ecosystem, agricultural activities, infrastructural facilities and amenities, injury, illness, death, inhibition of access to education, health services, comfortable housing, drinking water and sanitation, aggravation of poverty and hunger, among others (Birmah *et al*., 2021; Musa *et al*., 2015 and Dallil *et al*., 2015). Thus, in order to mitigate the negative effects of flooding, several researchers have developed different models depending on the flood scenario (Asgary, 2006).

Despite the availability of several disaster management models, disasters are frequently managed inefficiently. Asgary (2006) states that disaster management is a newly developed discipline and profession. Thus, those in charge of managing disasters should continue to improve their models so that it remains a professional and scientific discipline. In Minna, floods usually occur along the bank of River Suka when Minna records an unprecedented amount of precipitation or when the river is inundated by a high amount of water from upstream. However, its effects can be mitigated or eliminated through drainage construction, which unfortunately does not cover the entire length of the study area (Dallil *et al*., 2015). The southern part of Minna usually experiences floods to some degree that usually result in disaster. Hence, the aim is to develop a digital terrain model for planning and disaster management and to further understand the flood patterns of Minna.

1.1 Study Area

The study area of this project covers part of Bosso and Chanchaga local government area of Minna, Niger State. Lying on latitude and longitude of 9º36'30" N, 6º31'11" E and 9º35'47", 6º34'42". Niger State is one of the 36 states in Nigeria. The state was created on the 3rd of February 1976 out of the northwestern region of Nigeria. Minna is the capital with different ethnic groups of people speaking diverse languages, but Nupe and Gbagyi are predominant. The major activity of the people is farming. Figure 1 below describes the study area. The population of Minna, the capital of Niger State, Nigeria, is projected to be 513,000 in 2024. This is a 3.43% increase from 2023 when the population was 496,000. Minna is located in the North-Central geopolitical zone of Nigeria. It has a land area of 6,789 square kilometers and a population density of 34.48 people per square kilometer. The main reason Minna was selected is due to the constant and continuous flooding experience within the southern parts. Another factor was the frequent rural-urban migration which resulted in building houses without government approval (Odaudu and Musa, 2018).

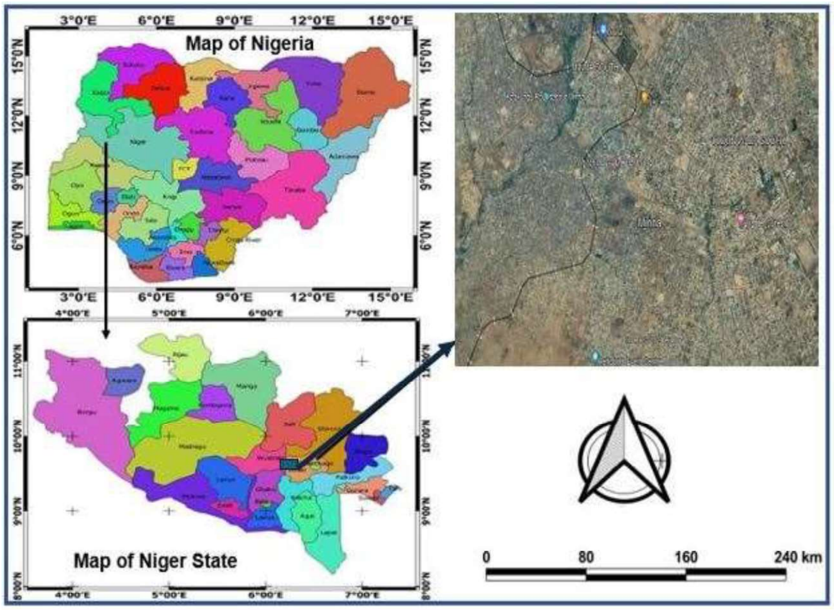

Figure 1. Study area embellished map showing the area of the project. Source: Google earth and processed in the lab.

2. Material and Method

This section describes the procedures used to achieve the purpose of this research. In this phase, the site was visited, "though some parts" in order to understand the physical nature of the study area**.** Garmin 76 handheld GPS was used to pick some points for reference purposes. Consequently, Figure 2 describes the methodology flow chart used for the execution of the project. In addition, the data employed in this investigation comprises a digital elevation model and other types of data as presented in Table 1 below. The data to use for this project are from the years 2023 and 2024, while the Land use data are for 1990, 2005, and 2020, respectively.

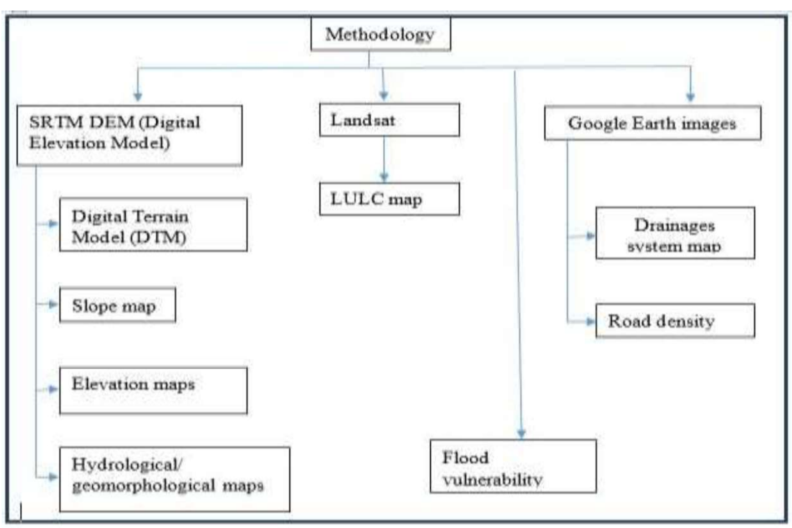

Figure 2: Methodology flow chart. Source: Research lap

Table :1 Data source and data type used in this project

SN	Data description	Data type/ resolution	Year	Source
1	LANDSAT-8 OL1	Satellite images	1990, 2005 and 2020	usgs.gov/landsat-missions/landsat-8
2	Aster DEM	25m	2023	OpenDEM
3	Google-Earth image		2024	Google-earth engine
4	Ground control points	±2m	2024	Garmin handheld GPS.

2.1 Land use land cover data processing and Geomorphology

The land use land cover of the study area was done to evaluate the development trend that have occurred over the years starting from 1990, 2005 and 2020; indicating fifteen years interval. The components that determine the trend were classified into five (5); namely vegetation, built-up, forest, bare land, water and agriculture. The Landsat imagery was downloaded from the USGS website in Tagged Image File Format (tiff) for the years 1990, 2005, and 2020, as shown in Table 1. Image enhancement was conducted to improve the quality of the data by removing errors caused by the atmospheric condition, scan line error, and radiometry effect using QGIS software.

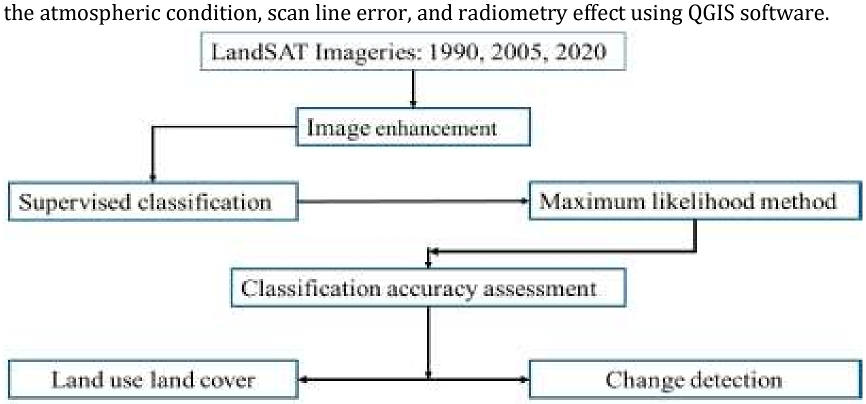

Figure 3: Land use land cover procedures. Source: Research lap

The raster calculator tool was used to perform the atmospheric correction, and the Fix Landsat 7 scanline error tool was used to correct the scanline error of Landsat 7”**.** Additionally, the RGB band was obtained using the composite tool in the raster processing toolbox. These processes were performed for all the imagery of the project area. Supervised classification was employed by selecting the training samples. The final classification accuracy assessment obtained is 85.8% by comparing the pixels and polygon of the classified image against the ground-referenced data.

2.2 Digital Elevation Model Processing and Development of the Geomorphology

The STRM digital elevation model from OpenDEM obtained from the United State Geological Survey (USGS) archieve was processed using QGIS 3.16.3 with GRASS 7.8.5 software within the QGIS environment. The image was processed to produce the digital terrain model (DTM) of the study area which represent the topographic nature of the terrain. Figure 4 shows the digital terrain model (DTM) in the QGIS software working environment. Consequently, Figure 5 shows the developed vulnerability DEM for the study area. The project developed the geomorphology of the study area to understand the dynamics of the flow characteristics. The development of the channel network distance, analytical hill shade, drainage basins, the stream network, slope map, aspect map, and the topographic wetness map were all done in the QGIS environment.

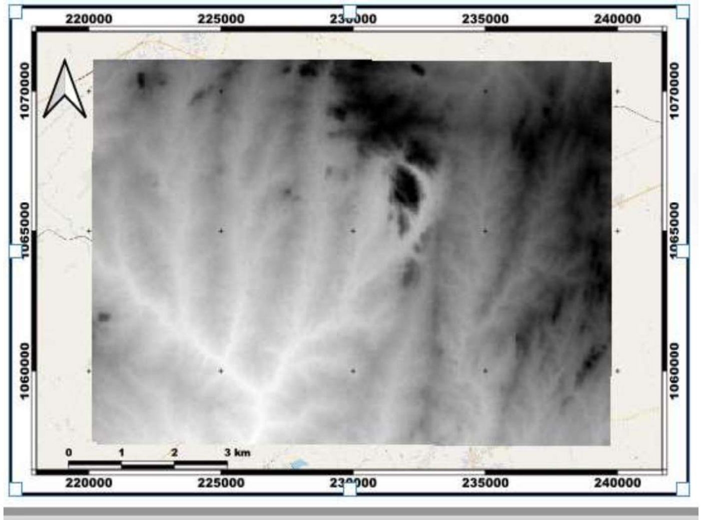

Figure 4: Developed DEM of the Study area

3. Result and Discussion

3.1 Land Use Land Cover Outcome

The results of the analysis were carried out for the land use trend of the study area. Figure 4 below shows the land use land cover of Minna City for the 1990(a), 2005(b), and 2020(c). In 1990, land was dominated by agricultural land (50%), followed by vegetation land (30%). The built-up area was less than 10% indicating that urban heat stress was limited. It was observed that the built-up area concentrated at the center and north-western segments of the city (Fig. 4).

In 2005, bare ground dominated the land use type of Minna city and environs at 45% (Fig. 4b). This was followed by agricultural land at the rate of 35%. The built-up area occupied 15% of the entire land surface area of the city, indicating a moderate rise from the previous decades. In this year, built-up area was found to be concentrated in the centre and around all segments of the city. This implies that urban heat must have increased, making the city more uncomfortable for the inhabitants. In 2020, the land use type showed a rise in agricultural land at the rate of 37% (Figs.4a and 4.b). This was followed by bare ground at an alarming increase of 36%.

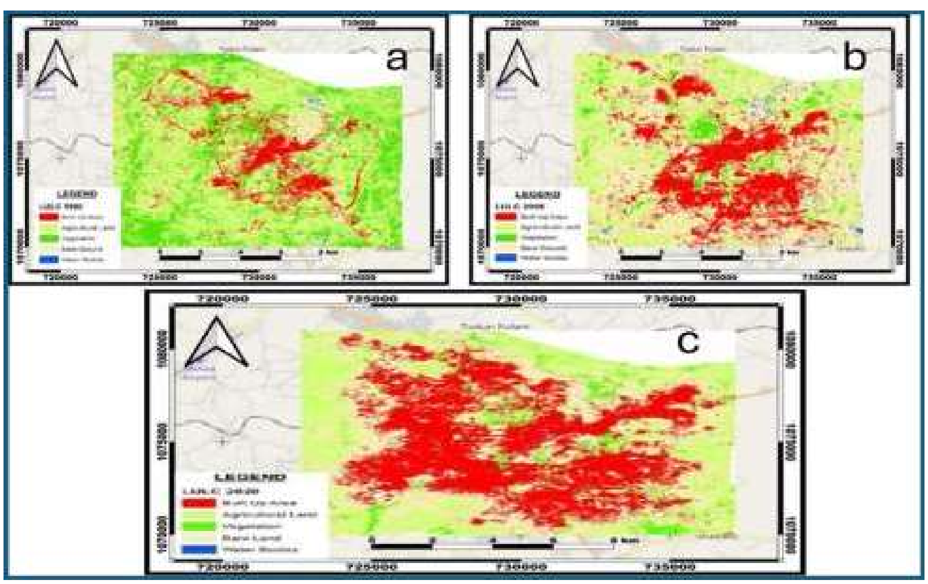

Figure 4: Land use land cover of Minna City of 1990(a), 2005(b) and 2020(c). Source: Research lap

3.2 Flood Vulnerability Map

Flood vulnerability measures the level of proneness of any area, infrastructure, or ecosystem to flooding. It considers geography, land use, infrastructural resilience, and community preparation (Vignesh *et al*., 2021). Flood vulnerability of the study area was developed as presented in Figure 4.. The color scale varies from red to blue indicating high and low points within the study area. In addition, the project-output as depicted in Figure 4 shows that Minna topography rises and fall at the southern section. This observation suggests that southern parts of the study area are under danger in the event of flooding. However, the saving advantage is that Minna main city has larger and deeper culverts which is controlling most average flooding scenarios. Climate variability and human-induced factors have exacerbated the flood recently, leading to increased displacement across Nigeria, which is in agreement with Dalil *et al*., 2014. However, other researchers like Dalil *et al*. 2014 and Musa *et al*., 2018 researched on flood impact on the Minna metropolis without looking at the hydrological components that exacerbate flood impact at any given instance of flood disaster.

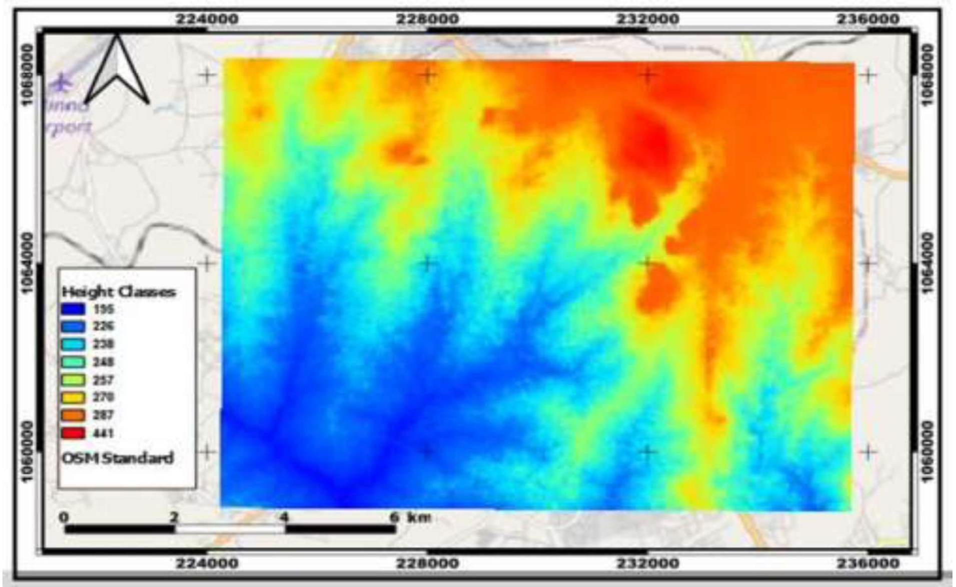

Figure 5: Flood vulnerability Map of Minna City center

4. Conclusion

In this study, a geospatial technique was used for mapping and analyzing flood extent and the vulnerable areas. The vulnerable areas were displayed using buffering and pointing out the risk zones areas. The land use and land cover map shows the increase in the built-up area owing to inflow of people and decrease in the vegetation over the years. Minna is a fast growing area due to its administrative and commercial center of Niger state. The research found out that there are increased physical planning problems as buildings are constructed on mostly all the available space including the marginal flood plains and river banks. The project revealed that hhe topography of Minna is slopy and steep towards the southern region which is another contributing factor of frequent floods in axis. The result that obstruction of water channels and drainage lines are also components leading to flooding. The dumping of refuse and dirt along river channels has reduced the free flow of water which leads to flooding in the study area.

Although, previous researches have shown that a hundred percent (100%) success of flood control may not always be achieved especially in urban environment yet, their damaging effects can be mitigated through management measures that are carefully designed by the government or affected communities. These must be effectively and economically funded and supervised.

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