ANALYSIS AND MAPPING OF AREAS VULNERABLE TO FLOOD IN YOLA METROPOLIS.

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Abstract
Intensification in the occurrence of floods globally and indeed in Nigeria with their devastating impacts on lives and properties is worrisome. To this end, the study involved Analysis and Mapping of Areas Vulnerable to Flood in Yola Metropolis. The purposive sampling technique was applied to select five judged worst flood vulnerable areas. Data were acquired through field observation, historical records, and hydrological data. Geographic Information System and Global Positioning System were applied in processing acquired spatial information. The result showed that the bulk of the study area is exposed to flood due to its low altitude, most of the areas are made up of planes with a gradient less than 1.6 thus highly vulnerable, areas with a gradient of 1.7 to 4.5 were marginally vulnerable and most of the areas were already developed, thereby increasing the susceptibility of the inhabitants to flood. Most parts of the communities were within a kilometre to river Benue and Chonji which is high vulnerability to flood. Doubeli, Jambutu, Limawa, and Rumde areas are within the zones with a high tendency for flow accumulation while the Bole-Yolde Pate ward is within areas with low tendency. Also, identified that clay soil is highly vulnerable due to its low infiltration, clay-loam is vulnerable, while sandy and sandy-loam which have high infiltration are not vulnerable. The study concludes and recommends that Government should come up with a policy that restricts development along with or around flood vulnerable areas and advice those already living in such areas to relocate. Also, results obtained in this study could be used by stakeholders and the government as a guide for effective flood management.

Keywords: Analysis; Flood Incidence; Mapping; Vulnerable Areas.

INTRODUCTION

Flood is one of the foremost environmental disasters that often constitute hazards to people leaving in flood vulnerable areas such as riverine and waterlogged areas. Flood vulnerability is the degree of damage to the lives and property of people in a flood-prone area [1]. A flood is defined as excess water flowing on the usually dry area. The occurrence of floods worldwide is considered the frequent naturally occurring hazard responsible for a more significant number of fatalities globally [2]. It is attributed to global warming, climate change, ocean swell/surge, and torrential rains. Thus, the effect of extreme flooding is dramatic, not only at the individual household level but in the country as a whole. From 1982 to 2014, the EM-DAT database recorded over 700 flood disasters globally accounting for 25% of global disaster losses. A 35% increase in flood risk was also reported by the United Nations which is driven by the increasing exposure of people and economic assets to the menace in the past decades [3]. In many African countries for example Nigeria, flooding has impoverished hundreds of thousands of people through displacement from homes and loss of tangible properties [4].

The problem of floods in Nigeria and particularly in Yola has spanned over a long period and is associated with many factors. Among these factors is the increase in population and rapid urbanization aggravated by urban sprawl, unplanned development, climate change, poor construction of drainage system, poor spatial planning, poor environmental awareness, and early warning system, inadequate waste management, and failure of government and physical planning machinery [5]. These challenges coupled with the sprawling of communities towards flood-prone areas rendering people and properties vulnerable are issues of concern. Daniel et al., [6] simply put, a solution to curbing this menace will mean saving millions of lives and properties.

Floods incidences are becoming a more frequent occurrence in Nigeria. Between 2011 and 2012, there were several reported cases of floods in several parts of the country [7]. In Yola, Adamawa state, the perennial problems of flooding cannot be overemphasized. Adamawa State Emergency Management Agency (SEMA) and many other agencies have reported several incidences of floods in the state. According to SEMA [8], in 2019, 15 people were killed due to floods, 280 houses/shelters were destroyed and 5,454 households were affected in nine local government areas – Demsa, Fufore, Ganye, Girei, Mayo-Belwa, Shelleng, Song, Yola North, and Yola South. July 2020, there was a report of floods that wreaked havoc in Yola metropolis, affecting communities in both Yola North and Yola South Local Government Areas, including Bachure, Damilu, Jambutu, Kofare, Tashar Sani, and Yolde Pate. In that flood, about 227 houses, 300 farmlands, and over 2,000 people were affected [9]. In August 2021, it was recorded, 7 people were killed and about 74,713 people were affected in 79 communities in 16 local government areas across the state, farmland, other valuables inclusive were destroyed [10], to mention a few. These persistent occurrences have prompted a lot of studies on flooding in the state to find solutions. A study done by Nwilo Olayinka and A'dzandeh [11], analyzed the exposures of land use/land cover and soil permeability to flood and model flood peak zones for three flow rates (2 years, 5 years, and 10 years) particularly the peak zones in the Adamawa catchment. Zarma, Sangari, and Ogah, [12] undertook a study on the identification and classification of areas liable to flood within Greater Yola, Adamawa State, Nigeria, with a focus on socio-economic vulnerability. Ezra, Takana, and Timothy, [13], work on Flood Vulnerability Assessment and Risk Management of Greater Yola, Adamawa State, Nigeria. They work on Land use/Land cover maps, derivation of flood vulnerability, development of flood vulnerability and risk model, and development of optimal sites for residential development. The first study (i.e 2019) assessed settlements affected by floods in the entire state of

Adamawa. This studies may not have captured some areas or provided details due to the large coverage of the studies. The last two (2020 and 2021) studies were able to narrow their scope to Greater Yola, though had a different purpose but their coverage was the entire Yola Metropolis.
However, the present study narrowed down to Jimeta and Yola sprawl areas with a focus on selected areas of Bole-Yolde Pate, Doubeli, Jambutu, Limawa, and Runde, particularly areas within 1.5km from water bodies that may be vulnerable to flood hazards. It is analysis and development of elevation vulnerability maps, slope analysis, flow direction analysis, flow accumulation vulnerability analysis, soil factor vulnerability analysis, and distance from river vulnerability analysis, overall vulnerability map, and vulnerable land-use map of the Study area.
Thus, this study attempted to address the challenges of flood hazards in the Yola metropolis, through analysis and mapping out areas that are vulnerable to flood hazards.

METHODOLOGY

This study involved the development of maps and analysis. Thus, data were acquired through field observation, historical records, hydrological data (Rainfall, water level, and runoff), and the use of GIS and GPS tools. Five judged worst flood-affected areas were selected as sample units for this work, they include Bole-Yolde Pate, Doubeli, Jambutu, Limawa, and Rude.

The Study Area

Yola metropolis (Greater Yola) is located in the south bank of the Benue River in Adamawa state, Northeastern Nigeria, within the Upper Benue catchment area with the coordinate 9°13′48″N, 12°27′36″E. It is bounded to the north by Gerri, to the East and South by Fufore, and to the West by Demsa local government areas respectively. It is the administrative and commercial center of the state. It has attracted an influx of people from all the local government areas of the state and beyond. Demand for housing to accommodate the unprecedented population led to the sprawling of communities to flood-prone areas. Yola occupies an area of 831 km^2 with a projected population (2017) from the 2006 census of 565,793 (3.3% National growth rate) and a population density of 681/km^2 [5].

Preparation of Maps

Elevation map was created from the digital terrain model (DEM) acquired from the United States Geological Surveys (USGS) spatial portal. The data was clipped to the study area's *Areal Extent* to extract elevation data covering Jimeta/Yola. The elevation values were classified into five categories range; as follows: 145 – 165, 165.01 - 179, 179.01 – 197, 197.01 – 239, and 239.01 – 296 meters respectively. An elevation between 145 to 180 meters above sea level is considered floodplains and above 180 meters above sea level is considered uplands. ArcMap was used for clipping and classification. The relief maps were created using ArcGIS's hydrological tools. The delineated DEM served as an input raster for firstly creating a flow direction raster which shows the direction of flow out of each cell. GIS was used to process and create variable factor maps indicating vulnerability suppositions for each candidate variable, using expert judgments inputs. The inputs were used in reclassifying pixel values of each candidate factor from the original classified values to new values. The new values of "0" - were areas that are not vulnerable, "1" as averagely vulnerable, and "2" as highly vulnerable areas.

RESULT AND DISCUSSION

Elevation Vulnerability Map

Figure 4.1 showed Digital Elevation Model (DEM) of the study area. It indicated that the area has an undulating surface with some areas having an altitude of 239.01m above sea level whereas low laying areas have an altitude below 165m. These situations make the low-laying areas exposed to flood hazards in the event of heavy rainfall and the surrounding rivers overtopping their banks.

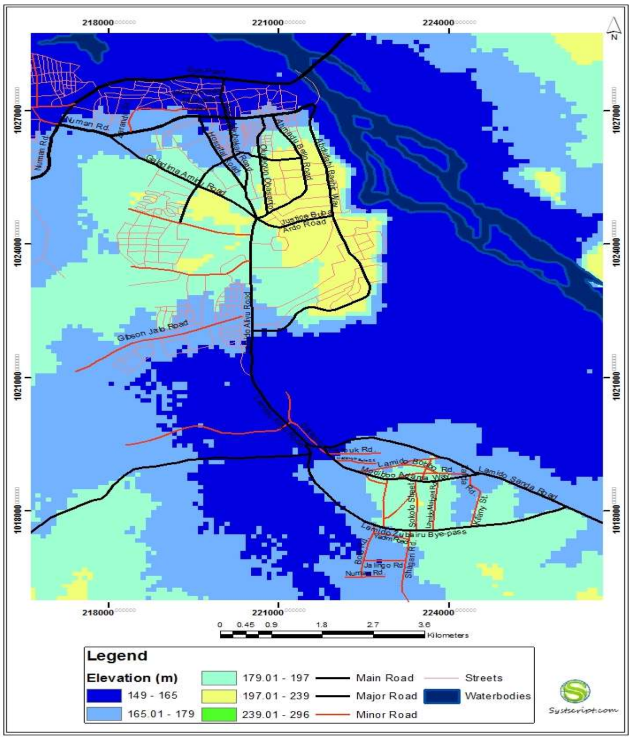

Fig.4.1: Digital Elevation Map (Source: Author's work, 2018)

Slope Analysis

Slope influences flow direction and distribution of surface and underground runoff to low laying areas and some extent the infiltration rate. Areas with Steeper slopes do experience high-velocity runoff and low infiltration during heavy rainfall, making them less vulnerable to flood hazards. Whereas areas with a gentle slope and flat surface do experience slow runoff velocity and are more susceptible to water-logging when the water exceeds the infiltration rate of the area. The slope analysis in figure 4.3 showed that most of the areas are made up of planes with a gradient less than 1.6 and highly vulnerable, while areas with gradients of 1.7- 4.5 were marginally vulnerable. And only a few mountainous areas with a gradient above 4.6 were not vulnerable. Most of these flow pathways and floodplains are now developed, thereby increasing the risk of the inhabitants to flood disaster (Figure 4.2).

Flow Direction Analysis

The map in figure 4.3 of the flow direction of surface and underground runoffs of the study area showed that the highland of Dougire and Mbamba is the recharge zones. And flow toward north-western and south-eastern parts of Jambutu, Yolde-pate, and Shagari been the discharge zones, while the slope of the path-way (flow directions) determine the onset of flow.

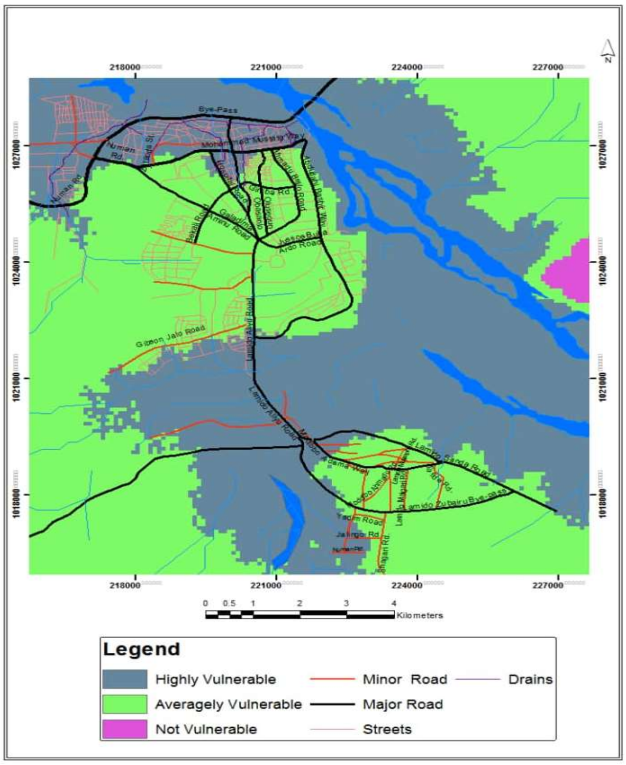

Fig. 4.2: Slope map (Source: Author's work)

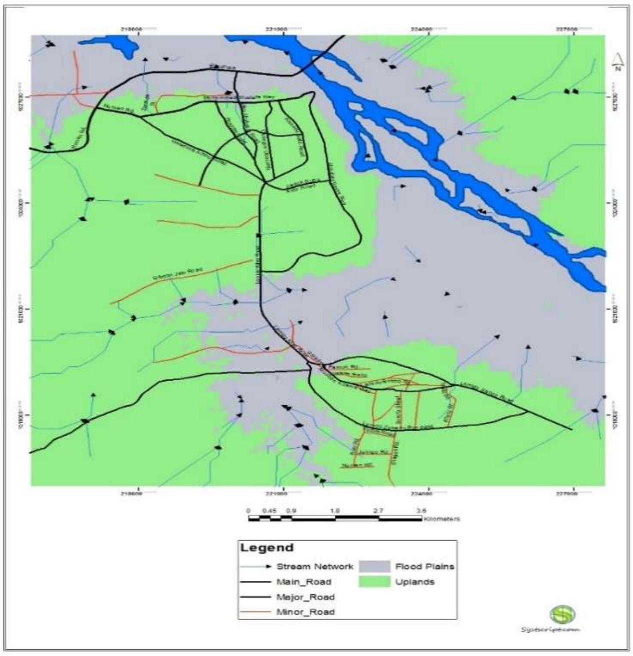

Fig. 4.3: Flow Direction.

Flow Accumulation Vulnerability Map

Flow accumulation shows potential water accumulation in the event of rainfall based on flow direction which is influenced by the slope. The flow accumulation analysis in figure 4.4 below showed that most areas close to River Benue and its tributaries have a very high tendency for flow accumulation which covers most parts of Jimeta, which constitute the floodplains of River Benue, river Chochi, and their tributaries. Doubeli, Jambutu, Limawa, and Rumde wards are within the zones with a high tendency for flow accumulation (see areas with pink color – fig. 4.4). On the other hand, most areas within Yola town have a very low tendency for flow accumulation, which indicates that Bole-Yolde Pate ward is within areas with a low tendency (1-8%) for flow accumulation (See areas with sky blue colors – fig 4.4).

Soil factor Vulnerability

The soil analysis identified 5 types of soil in the study area, it includes clay, clay-loam, loam, sandy loam, and sandy soil. Based on the soil categories, figure 4.6 indicates that the soil of most parts of the study area is of the clay-loam type which has low infiltration capacity and is vulnerable to flood. Followed by clay soil which covers the bank of River Benue with a very poor infiltration rate and is highly vulnerable to flood while only a few areas are of the sandy and sandy-loam, this soil type has a high infiltration rate and low runoff potential as such it is not vulnerable (Figure 4.5).

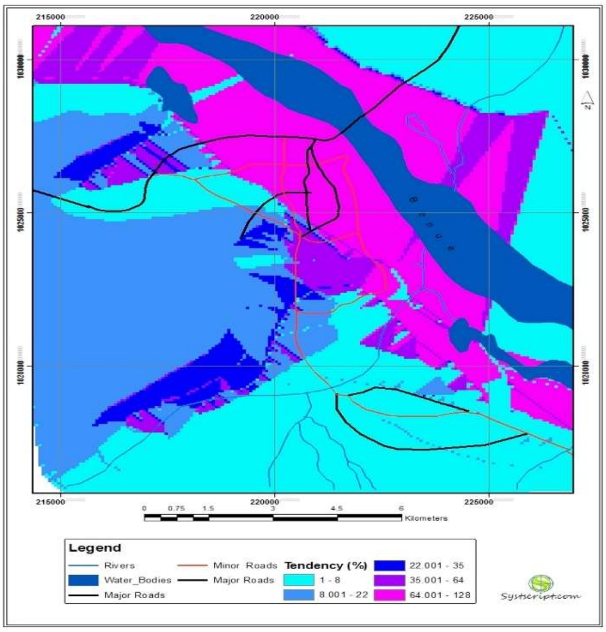

Fig. 4.4: Flow Accumulation

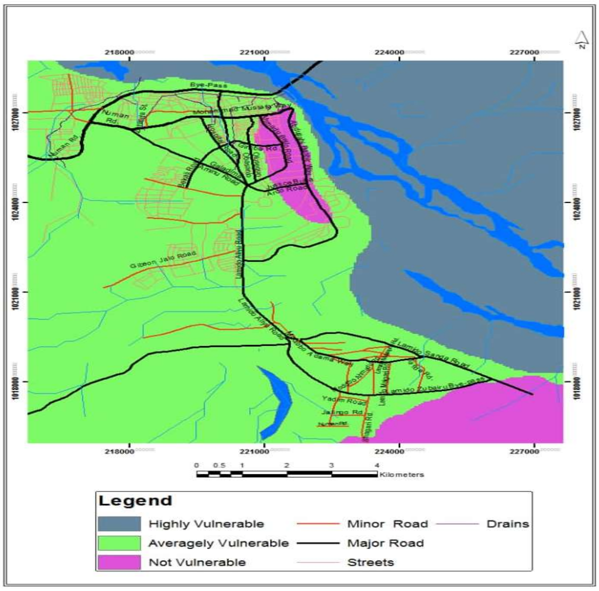

Fig. 4.5: Soil Vulnerability of the Study Area

Distance from River Vulnerability Analysis

Figures 4.6 showed the distance of different locations from the water body and their level of vulnerability. Field observation and distance analysis have shown that the majority of the study area was within a 1.5km distance to the nearest water body and highly vulnerable to flood hazards which are mostly sprawled areas while the core or old towns of Jimeta and Yola were averagely vulnerable. It also revealed that all the sample units (areas) are highly vulnerable.

Overall Vulnerability Map of the Study Area

Areas that are expected to carry floods were ranked according to spatial risk factors to establish the most vulnerable places in the event of floods. All the above-mentioned parameters were used to determine the hazardous areas in the study area. These parameters were computed and entered in the attribute table of the catchment, and by comparing the variations within the data. Figure 4.7 identified the overall vulnerability of flood hazards in the study area considering all the flood causative factors, land uses, and other intensifying factors. It reveals that almost fifty percent of the entire study area is highly vulnerable to flood hazards with less than ten percent not vulnerable.

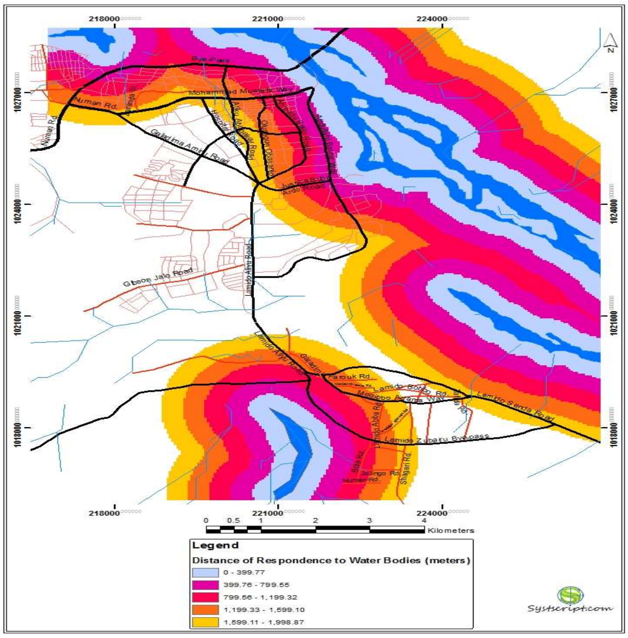

Fig. 4.6: Vulnerability of the study area based on distance

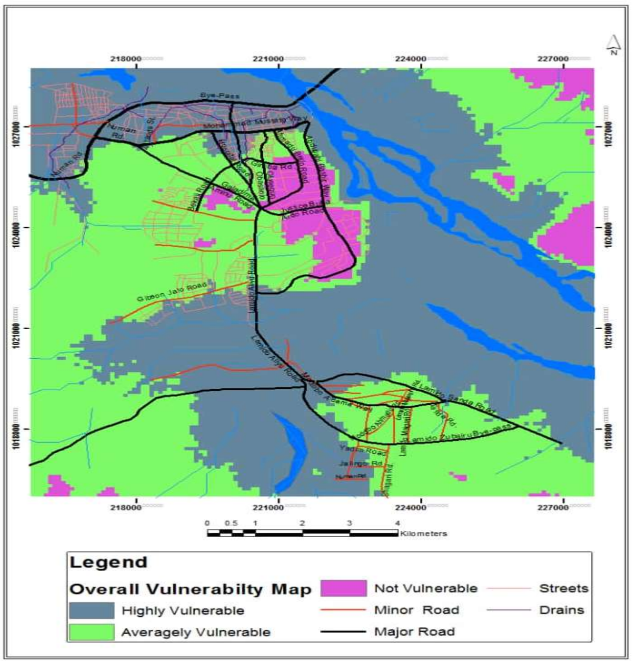

Fig. 4.7: Overall Vulnerability Map of the Study Area

Discussion

The result showed that the bulk of the study area is exposed to flood due to its low altitude and most of the areas are made up of planes with a gradient less than 1.6 were highly vulnerable while areas with a gradient of 1.7- 4.5 were marginally vulnerable with most of the areas already developed, thereby increasing the risk of the inhabitants to flood disaster. Also, proximity to water bodies intensify vulnerability to flooding hazard. These findings aligned with Obiora-Okeke [14] who

confirmed in his study on Flood vulnerability mapping of Ogbese, Nigeria that low-lying areas are more prone to flooding. It also justifies studies done by Onuigbo, Ibrahim, Agada [15]; Emmanuel and Aniekan, [16]; Ezra, Takana, and Timothy [13] who established that proximity to water bodies and elevation intensify flood vulnerability.
The result on flow accumulation vulnerability indicated that Doubeli, Jambutu, Limawa, and Rumde wards are within the zones with a high tendency for flow accumulation while Bole-Yolde Pate ward is within areas with low tendency. Also indicated that clay-loam soil has low infiltration capacity and is vulnerable to flood and clay soil which cover the bank of River Benue with a very poor infiltration rate is highly vulnerable to flood. On the land use map, it showed that about fifty percent of developed or built-up areas in the study area were vulnerable to flood due to encroachment. Ezra, Takana, and Timothy [13] observed the same problem, built-up areas were vulnerable to flood due to encroachment of development towards flood-prone areas.

CONCLUSION AND RECOMMENDATION

This study has provided maps and vital information to be used as measures towards reducing the flood hazard in the study area. It shows how maps can be used as flood control or reduction measures and how GIS is a powerful planning tool used in various capacities. The study, therefore, recommends that Government should come up with a policy that vehemently restricts development along or around flood-prone areas and advice those already living in such areas to relocate or vacate the area immediately and that results obtained in this study could be used by stakeholders and government as a guide for effective flood management.

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