Physical Flood Vulnerability in Kogi State of Nigeria

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Abstract

As a result of yearly intense rainfall flooding has become a predominant cause of disruption to lives and properties in Kogi State. In July 2019, extreme rainfall events occurred in the state leading to severe flooding that caused serious damage to both public and private properties. More extreme flooding occurred in August 2021. Vulnerability study is a sine-qua non for any hazard. Currently, in the majority of local government areas in the state there are limitations to the development of master plans such as inadequate data for analysis and characteristics of the flood plains, thus, developing flood vulnerability maps as prerequisites for effective planning becomes imperative. This work aimed at identifying the areas prone to physical flood in the study area as a guide to development and protect citizens against hazards using GIS and proffering ways to minimize their vulnerability. Previous findings showed that the study area is characterized by high rainfall waters, low elevation and low Normalized Difference Vegetative Index (NDVI) thus rendering it highly vulnerability to flood.

Keywords:Analytical Hierarchical Process, Flood, Geographic Information System (GIS), Hazards, Vulnerability

Introduction

Vulnerability can generally be described as a potential for loss (Cutter, 1996; Cutter, Boruff, & Shirley, 2003). Vulnerability is a major component of hazard since it is defined by individual and behavioral factors, location, governmental policies, culture and history, it is highly dependent on hazard.
This can include things such as land use, public infrastructure, the burden of disease in the population and previous exposure to hazards (Saulnier, Dixit, Nunes, & Murray, 2020)
There are three basic components of flood vulnerability; Physical vulnerability of people and infrastructure; Unfavourable organizational and economic conditions; and Attitudes and motivations. Physical vulnerability is defined as the properties of physical structures that determine their potential damage in case of a disaster (e.g, material type and construction quality) (Ebert, Kerle, & Stein, 2009).

A knowledge of the vulnerability posed by the flood and its control are a major challenge. Kogi State is plagued with flood as a result of the frequency of the rainfall and other physical factors. Increased occurrence of extreme rainfall events arising from climate variability and change increases the probability of flood occurrence (Ibidun, 2010). In all natural disasters in Kogi State, flooding appears to be on the top ranking in terms of coverage area, vulnerability, and frequency. This present work studies physical vulnerability of Kogi state in a bid to identify the local government areas that are vulnerable to physical flood to serve as input in the development of master plans. Inputs to the study are the Rainfall data, Elevation, Slope, Drainage density, soil, road, rivers Normalized Difference Vegetative Index (NDVI), Topographic Wetness Index (TWI) and Land Use Land Cover (LULC) data while Analytic Hierarchy Process (AHP) was the method adopted.
The TWI is a physically based index or indicator of the effect of local topography on runoff flow direction and accumulation (Ballerine, 2017). The index has applications in specialized rainfall runoff modeling and simulation of the spatial distribution of soil moisture and precision agriculture (Beven & Kirkby, 1979; Qin, et al., 2011).

METHODOLOGY

In situations where exposure or non-exposure to a hazard constitutes a risk that may actually result in a disaster, vulnerability comes to play. Rapid developments in the urban centers in the state is hampered by flood disasters which is on the rise. A policy plan to alleviate and guide these development requires a vulnerability assessment hence the inevitability of this study.
In this study, the Normalized Difference Vegetative Index (NDVI), Topographic Wetness Index (TWI) and Land Use Land Cover (LULC) data while were use while the Analytic Hierarchy Process (AHP) was the method adopted. All data were obtained from reliable online sources.

NDVI effectively permits us to classify those regions exclusively covered by water as "flooded". Smooth surfaces, for example, streets, paved roads, air terminal runways, bare grounds etc have backscatter mean value close to zero. All non-smooth surfaces (forests, bushes, agricultural regions, woods and horticulture etc) have a mean value well greater than zero. The minimum value of every pixel in the stack containing the flood images is utilized to catch a particular discontinuity in the time series, for example those pixels that during the flood show extremely low backscatter. The distinction between the mean and the base worth features those discontinuities, for example flood regions. Normalizing the differentiation allows us to have values some place in the range of 0 and 1 and besides, helps to define a cutoff to mark flood regions (Cian, Marconcini, & Ceccato, 2018).
Topography is often one of the major controls on the spatial pattern of saturated areas, which in turn is a key to understanding much of the variability in soils, hydrological processes, and stream water quality (Grabs, Seibert, Bishop, & Laudon, 2009). Topographic controls on hydrological processes are evaluated using the Topographic Wetness Index (TWI). This is applicable in characterizing biological processes including forest, site quality, vegetation patterns, and annual net primary production (Beven & Kirkby, 1979). It utilizes the topographic components of a terrain to determine the flow or accumulation of water. TWI was calculated from the digital elevation model raster and then by using several tools within the program the slope, flow direction, flow accumulation, tan of slope were calculated using simple equations. TWI is given by the following expressions:

DEM – Fill DEM – Flow direction – Slope (degree) – Slope (Radian) – Slope (Tan) – Scaled Flow accumulation = TWI

Human activities play an important part in virtually all natural systems and are forces for change in the environment at local, regional, and even global scales. Changes in land use and land use management, specifically, affect the hydrology that decides flood events. Deforestation, urbanization, and other land-use activities can change the seasonal and yearly conveyance of stream flow thereby causing floods.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is one of the different methods that have been developed for multi-criteria decision making. It is a multi-criteria decision making (MCDM) method that helps the decision-maker facing a complex problem with multiple conflicting and subjective criteria based on the judgments of experts to derive priority scales (Saaty, 2008). The judgments may be inconsistent, and how to measure inconsistency and improve the judgments, when possible to obtain better consistency is a concern of the AHP for example location or site selection, projects ranking and so forth. Expert judgments of professionals that are used for the weighting are obtained from existing literatures. All data used in this study were converted to raster, and reclassified using AHP weighted overlay.

The Study Area

Kogi State is one of the largest state in Nigeria, covering an extent of approximately 28.968km2 within the geographical coordinates of 778034.37mE, 943817.51mN and 348220.70mE, 774890.60mN. Kogi state is drained by the two major rivers in Nigeria; River Niger and River Benue and their tributaries; Mabolo river, Ofu river, Okura river,Ubele river, Inachalo river, and Oyi river (Ozim, Olufemi, Ekpo, Alamaeze, & Mban , 2021). The vegetation of the study area is made of rain forest in western part, wooded savanna and grass land in the eastern part, forest savanna mosaic to the south and Guinea savanna in the North (APOC, 1999). The climate of Kogi state is characterized by wet and dry AW type of koppen climate classification and annual rainfall of 1016mm and 1524 mm, which occurs between April and October and a mean annual temperature of 27.7^{o}c (Ozim *et al.* , 2021)

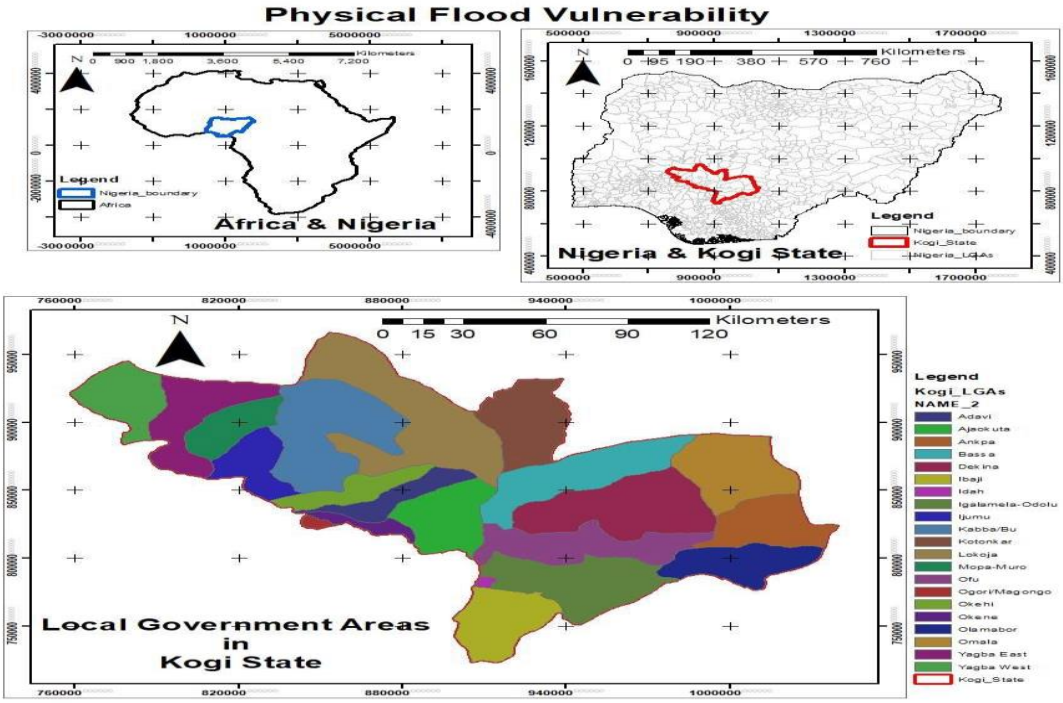


Figure 1: Study area (Authors)

Data Sources

Various Required data have been collected for different purposes and from different sources viz;

SN	Data	Source	Purpose
1	Elevation	NASA DEM	Data support prior to Hydraulic computations & modelling
2	LULC	(Advanced Land Observing Satellite, ALOS)	To estimate manning's value at each river cross section
3	Drainage Network details	(OSGOF)	Hydrographic data
4	Soil data	Harmonized World Soil	To determine the erodibility of river sedimentary
5	ESRI vector shapefiles of roads, streams, buildings etc covering the study area	Office of the Surveyor General of Lagos State.	storing the location, shape, and attributes of geographic features
6	NDVI	2018 Landsat 8 OLI image	To know how vegetative an area is.
7	Monthly rainfall data	Global Precipitation Measurement, GPM	Hydrologic modelling
8	TWI	Scaled flow accumulation	to quantify the topographic control on hydrological process

Vulnerability Assessment

This study looks at the Physical vulnerability of Kogi State to floods. It harnesses a methodical sequence of operations (such as spatial multi-criteria decision making and weighted overlay) adopted in mapping flood vulnerability in the state. For any flood combat, flood vulnerability study is a sine- qua non. Currently, majority of local government areas in the state do not have master plans to guide development and protect citizens against hazards. Besides, there are limitations to the development master plans such as inadequate data for analysis and characteristics of the flood plains, thus, developing flood vulnerability maps as prerequisites for effective planning becomes imperative. Flood indicators used (such as Rainfall, Elevation, Slope, Drainage density, NDVI, TWI, LULC, soil, road, rivers) are sourced from existing archives as well as online sources.
These indicators were reclassified into five vulnerability scale 1-5 where 1 represents 'very low', 2 represents 'low', 3 represent 'moderately low', 4 represent 'High' and 5 represents 'Very high'. Weighted overlay was performed on the reclassified identified flood factors (until a consistency ratio less than 0.1 was obtained) by Pairwise comparison method (Analytical Hierarchical Process (AHP) to finally prepare the flood vulnerability maps (figure 2).

RESULTS AND DISCUSSION

The study showed that while the minimum elevation of the state is between 18 & 48m the maximum elevation is between 145 & 247m. Part of Ifo LGA of Ogun state and Uzo wani LGA of Enugu state

Nigeria having elevation above this, still experience flood. This is one of the justifications that kogi state is vulnerable to flood. These low elevated areas fall within the Niger river course such as Ibaji, Idah, Igalamela, Ajaokuta, Lokoja, Bassa, ofu, Kotonkarfi, Omala LGAs. Besides, their low elevations, these regions also experience the highest rainfall throughout the year. The major land uses/cover in the area are water bodies, farmland, built up areas, bare grounds and vegetative covers. NDVI for the area was calculated to determine how vegetative the area is. NDVI ranges between -1 and 1. Regions with the least NDVI values (-1 to 0) are bare-ground, sand, rock, roads, buildings, water, snow, and cloud etc. these areas are more vulnerable to flood than areas with values between (0 to 1) such as plants and vegetation. The lowest NDVI in the state is between -0.1992 & 0.482. These range falls within the most vulnerable regions in the state (figure 2). Three (3) LGAs (Ibaji, Idah and Igalamela) in the state are categorized as very highly vulnerable, five (5) LGAs (Okene, Olamaboro, Ajaokuta, Ankpa and Ofu) are categorized as highly vulnerable and eight (8) LGAs (Adavi, Bassa, Dekina, Koton-karfi, Lokoja, Ogori, Okehi, and Omala) are moderately vulnerable while five (5) LGAs (Ijumu, Kaba, Mopa-Muro, Yagba East and Yagba West) have low vulnerability to flood, Table 1.

Table 1: LGAs Floods coverage area and % vulnerability

SN	LGA	Area (Km^2)	Vulnerability Coverage	% Vulnerability by State	% Vulnerability per LGA	Vulnerability
1	Ibaji	1377	1101.6	7.663650878	80	**Very High**
2	Idah	48	43.2	0.300535329	90	**Very High**
3	Igalamela-Odolu	1990	796	5.537641702	40	**Very High**
4	Okene	290	203	1.412237771	70	High
5	Olamaboro	1205	843.5	5.868091427	70	High
6	Ajaokuta	1371	959.7	6.676475806	70	High
7	Ankpa	1264	884.8	6.155408766	70	High
8	Ofu	1652	991.2	6.89561615	60	High
9	Adavi	715	429	2.984482777	60	Moderate
10	Bassa	1917	1341.9	9.335378643	70	Moderate
11	Dekina	2485	1242.5	8.643869114	50	Moderate
12	Koton Karfe	1528	764	5.31502294	50	Moderate
13	Lokoja	3396	2037.6	14.17524966	60	Moderate
14	Ogori/Magongo	75	37.5	0.260881362	50	Moderate
15	Okehi	728	436.8	3.0387461	60	Moderate
16	Omala	1746	873	6.073318098	50	Moderate
17	Ijumu	913	91.3	0.635159155	10	**Low**
18	Kabba/Bunu	2694	269.4	1.874171702	10	**Low**
19	Mopa-Muro	877	219.25	1.525286361	25	**Low**
20	Yagba East	1517	455.1	3.166056204	30	**Low**
21	Yagba West	1180	354	2.462720053	30	**Low**

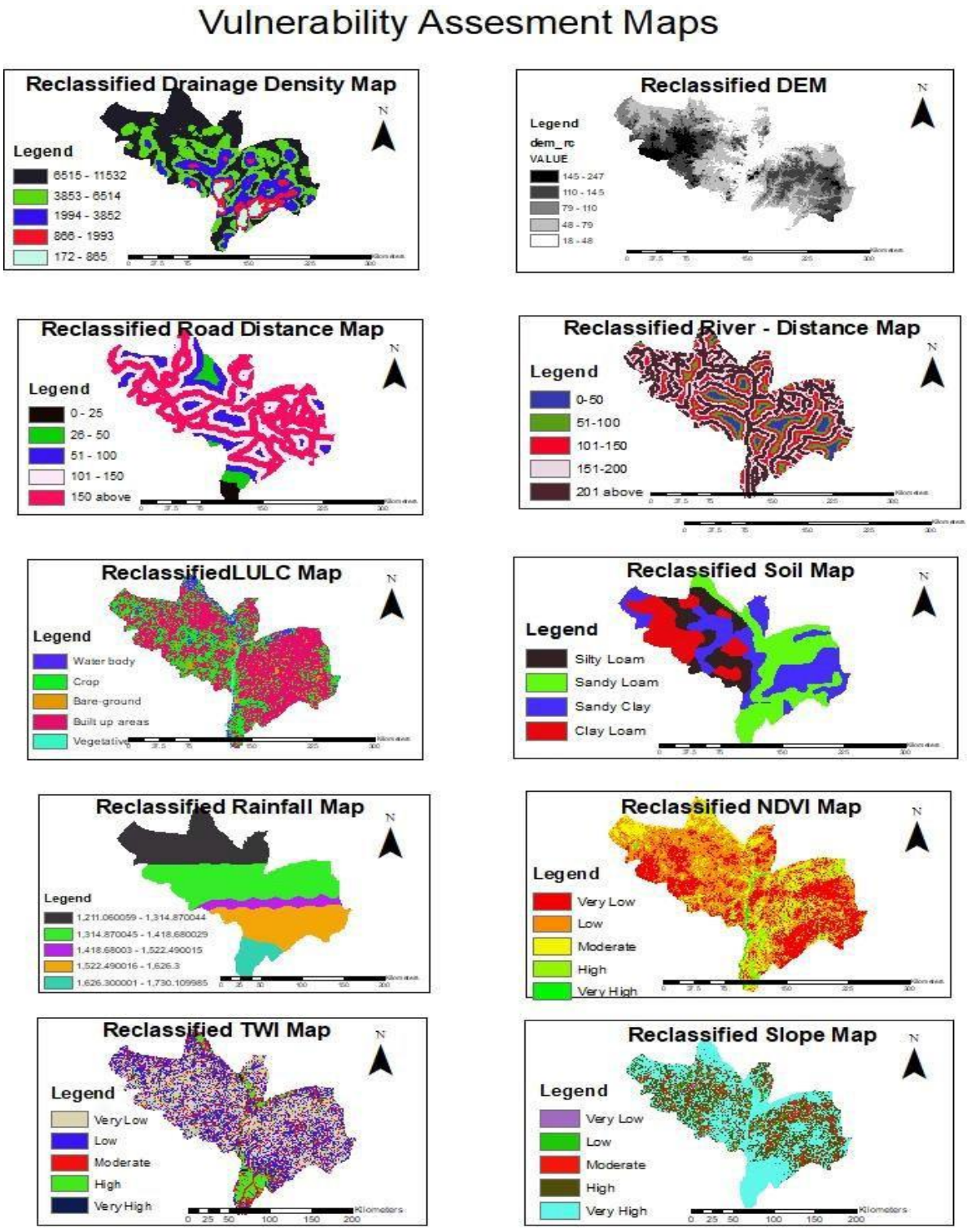


Figure 2: Flood vulnerability assessment maps

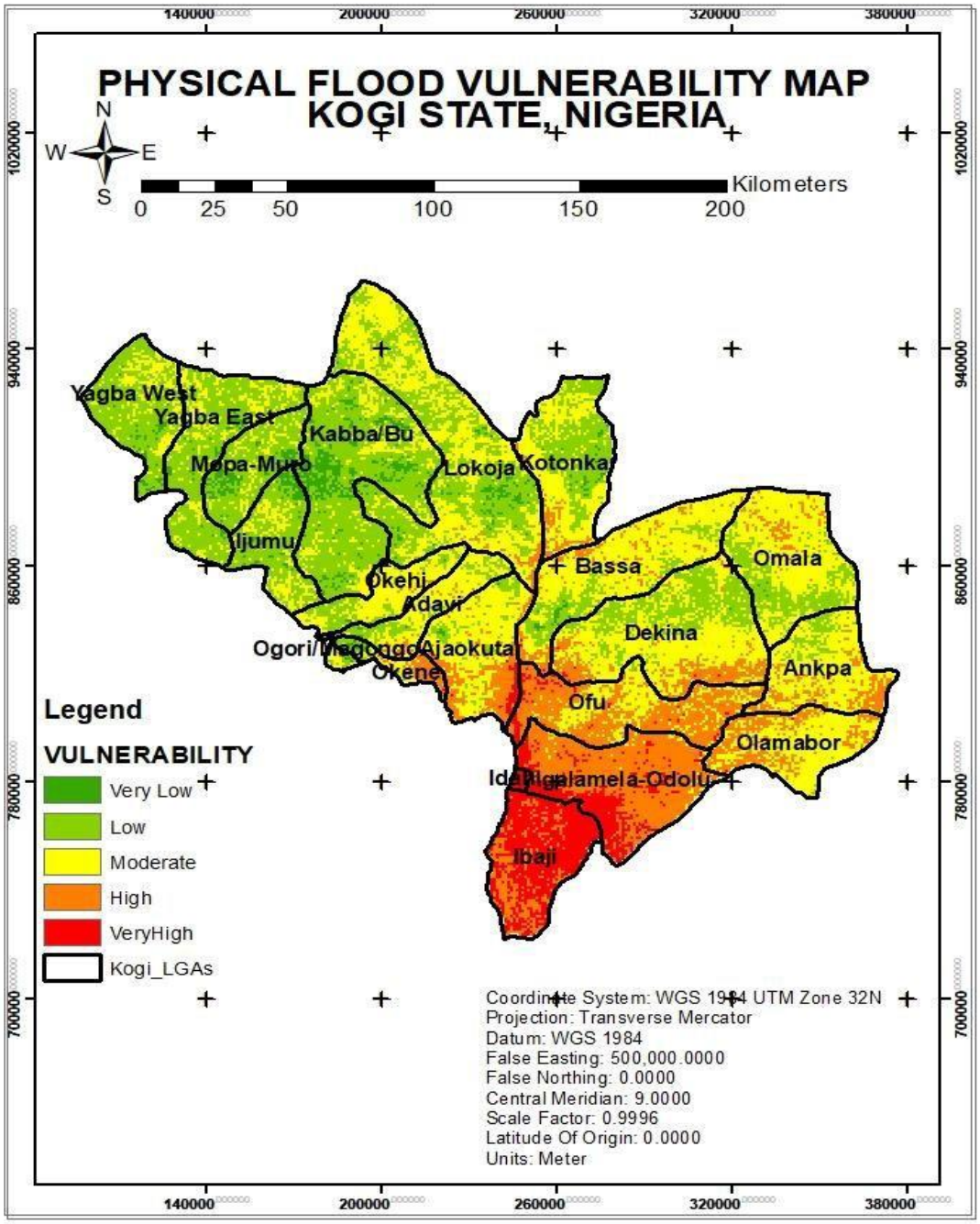


Figure 3: Vulnerability map

CONCLUSION

The physical flood vulnerability map of kogi state was prepared from natural factors such as Rainfall, Elevation, Slope, Drainage density, NDVI, TWI, LULC, soil, road, rivers, that were sourced from online resources. Areas closer to rivers and lower elevations tend to be physically vulnerable than areas with higher elevations and areas further away from rivers or water bodies (Figure 3).

RECOMMENDATIONS

The flood data and vulnerability maps generated from this present study can be used as a base for subsequent flood research and developing an alert system for related flood areas. There is also the need to monitor the various urban expansion and flood incidences within the LGAs using vulnerability maps.

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