International Journal of Frontline Research in
Engineering and Technology
Journal homepage: https://frontlinejournals.com/ijfret/
ISSN: 2945-4840 (Online)

(RESEARCH ARTICLE)

Check for updates

Analyzing flash flood risk in a section of ntawogba creek, Port Harcourt city, Rivers State

Richard JU [1, *], Ibochi Andrew Abah [2] and Ugwulebo BA [3]

[1] *Head Business Development, Office of the Surveyor General, Moscow Road, Port Harcourt, Nigeria.*
[2] *Department of Surveying & Geoinformatics Federal Polytechnic, Bauchi, Nigeria.*
[3] *Balis Geosystems Int'l Limited, Olu Obansanjo Road, Port Harcourt, Nigeria.*

International Journal of Frontline Research in Engineering and Technology, 2022, 01(01), 042–052

Publication history: Received on 16 February 2022; revised on 29 March 20222; accepted on 31 March 2022

Article DOI: https://doi.org/10.56355/ijfret.2022.1.1.0003

Abstract

Flood is a natural disaster and occurred in different forms. It is also a factor of climate change. Flash flood is a type of flood that occurs within few hours of intensive precipitation. It poses serious threat to urban areas, particularly in less developed countries. Geospatial technology has been very useful in mapping spatial extent and quantified damages associated with flash flood events. Proximity analysis and AHP has been widely utilized in modeling flash flood vulnerable zones. Little was known about MCA ranking method which is considered appropriate for few parameters in making complex decisions. This study utilized MCA ranking method to analyzed flash flood risk within Ntawogba Creek, Port Harcourt, Rivers State. Rainfall, slope model, impervious surface and distance to river were used in the decision making. The datasets were processed into common spatial referenced system. Each criterion was scaled from 5 to 1, with 5 being very high risk and 1 very low risk area. Weights were assigned to the criteria based on the importance, with higher weight to criterion that is more important in the decision making process. The weights are; distance to water channel 48, impervious surface 25, slope 22 and rainfall 5. The results obtained showed area of 93.0ha as very high flash flood risk representing 6% of the area. This zone was located along Ntawogba Creek and on major roads. Total area of high risk zone was 864.1ha representing 56%, moderate risk and low risk zone was 452.2ha and 134.7ha with 29.3 5 and 8.7% respectively. For further study, drainage density and soil infiltration should be included in the flash flood risk analysis.

Keywords: Google Earth Elevation; Flash Flood; Landsat 8; MCA; Risk; Slope model; TAMSAT

1. Introduction

Floods generally occurs in different types such as flash flood [1], ground water flood [2]; [3], urban flood [4], and coastal flood [5]. Of these, flash floods are common in our urban areas. Flash floods occur within a few minutes of hours of intensive rainfall or sudden dam failure [6]. Flash floods according to experts occur within 6 hours of intensive rainfall. It occurs in urban areas, along water channels and on mountainous areas and is associated with little warning [7]. Also, flash floods occurred in dry areas without stream channels and cause severe impacts on urban areas. The degree of damage depends on the proximity to river channel. In other words, the farthest the distance the less flash flood impacts. Lack or inadequate drainage systems [8] and impervious surfaces [9] aggravated flash flood disaster. Urbanization creates impervious surfaces due to construction of roads, buildings, bridges and recreational areas which increase the rate of runoff [10].

* Corresponding author: Richard JU
Head Business Development, Office of the Surveyor General, Moscow Road, Port Harcourt, Nigeria.

Flash flood is associated with vary degrees of impacts on both humans and properties. In 1976 flash flood caused 156 fatalities in Colorado and in 1977 Pennsylvania recorded 74 fatalities [11]. [12] analyzed the pattern and values of damage properties by flash flood in southeast United State between 1996 and 2017 and discovered that total properties damage in Florida and Georgia stood at $621m and $162m respectively.

Flash flood as spatial in nature and source, can be mapped using remote sensing and GIS technology. This geospatial technology provides better approach than traditional survey methods in mapping vulnerability and risk attributed to flash floods. The introduction of medium spatial resolution like Landsat data [13]; [14] and high spatial resolutions satellite image such as SPOT 5 [15] has also improved the efficiency of flash flood mapping and analysis. Accordingly, researchers have combined several spatial datasets in modeling flash flood risk and vulnerable zones. [16] Used land use/ land cover map derived from normalized difference vegetation index (NDVI) and morphometric factors derived from SRTM DEM to model watershed characteristics. In their study, NDVI was used to mapped urban impervious and the study observed 969ha as vulnerable zones to flash flood. Also [17] used Sentinel-2, SRTM, and online data to map vulnerability zones to flash flood in the city of Ras Gharib, Egypt. They used Analytical Hierarchy Process (AHP) to mapped flash flood vulnerability zones. The study determined spatial extent of flash flood by compared two epochs of Sentinel image. Similarly, [18] applied AHP by integrating distance to river, land use/ cover, slope map, soil influence, drainage density, surface roughness and run-off to mapped flash flood vulnerable areas in Najran city, Saudi Arabia. Flash flood high risk zones and the population affected were mapped from the hazard map and layers. Little knowledge has been known of MCA direct ranking method of integrating criteria with DEM derived from Google Earth Elevation (GEE). MCA has been considered appropriate for few criteria, hence, it was selected. In this study, Google Earth (GE) derived DEM which has been prove to have better accuracy than STRM and other geospatial datasets were used to mapped flash flood risk areas within Ntawogba Creek.

1.1 Study Area

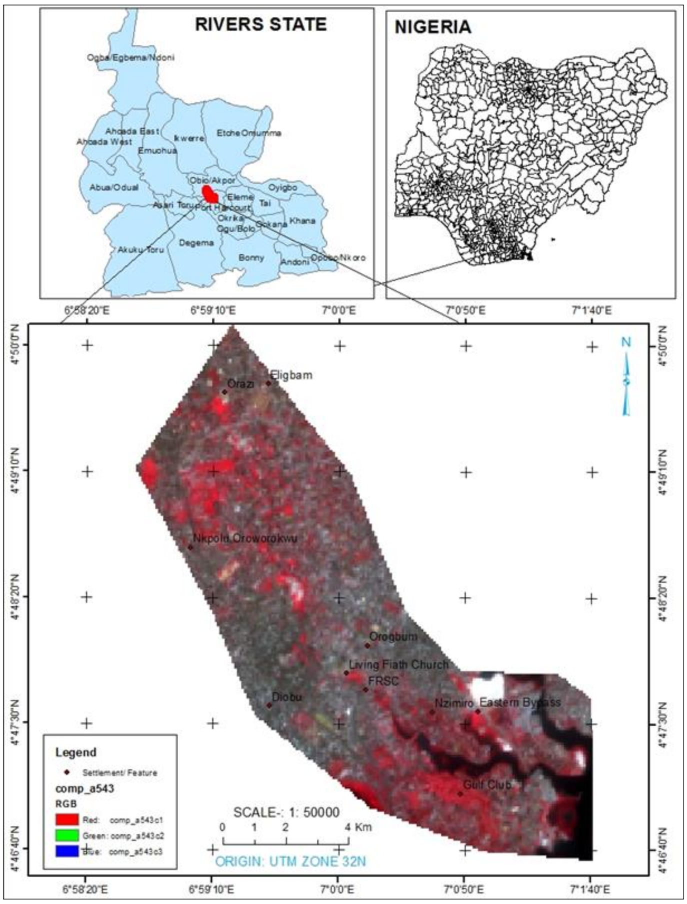


Figure 1 Study area location map with Rivers State and Nigeria as insert

The study area lies in the central part of Port Harcourt City, Rivers State, Nigeria with Ntawogba Creek traversing from south to north. It is located on longitude 275438mE – 281499mE and latitude 528250mN – 533229mN in WGS84 Zone 32N. It has an approximate area of 1563.50ha and the elevation ranges between 2.4m and 21.4m. The soil is predominantly Nitisols with about 30 percent clay, which enables it to hold water on the surface. Two seasons are prevalent in the study area and they are wet and dry seasons. Flash floods occur during wet season. As coastal city, the mean annual precipitation and temperature are 2,601.6mm and 23.2°C [19]. However, there is instance of abnormally in climate in which rainfall and temperature are above or below normal [20]. The available land use/ cover in the areas which controls the pattern of flash floods includes; built-up areas, roads, drainage systems, and water bodies. This study area was selected because of the recurrent flash floods, particular, the July 2017 and September 2020 flash flood with properties worth millions of naira destroyed. Study area map is as shown in figure 1.

2. Methodology

The study adopted Multi-Criteria Analysis (MCA) in ESRI's ArcGIS and other spatial analysis to model flash flood risk. Geospatial data were processed into uniform format and projection system prior to the analysis. The integrated datasets are slope, distance to river, impervious surface and rainfall. The flow chart of the research is depicted in figure 2.

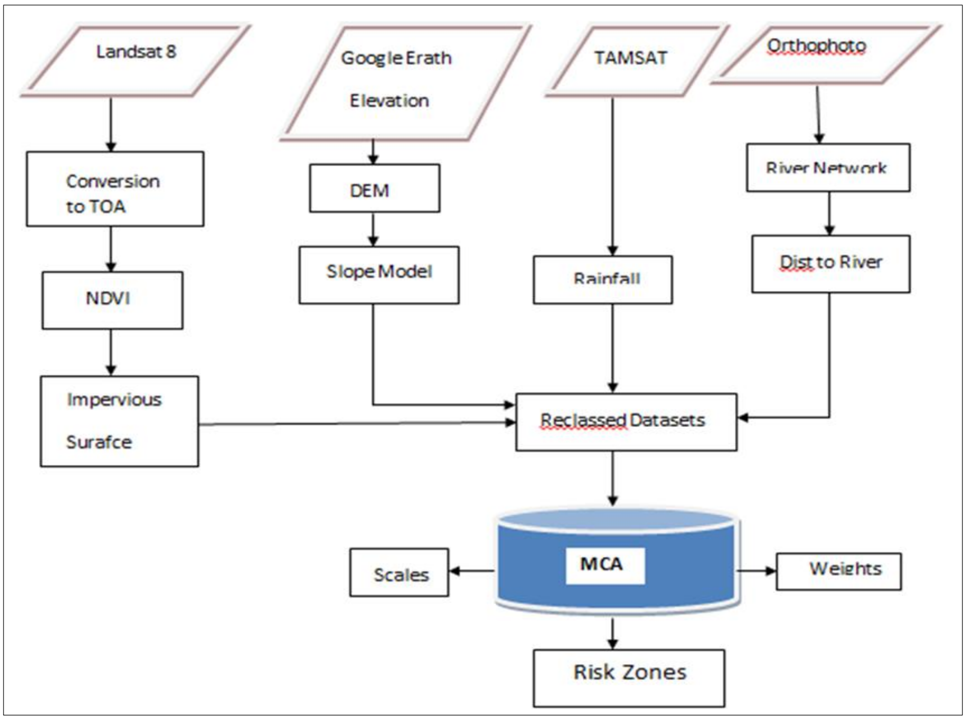


Figure 2 Flow chart of the methodology used in flash flood analysis

2.1 Software and Datasets

The following geospatial datasets and software were used to map flash flood risk zones in the study area. The datasets used for the study are digital elevation model (DEM) obtained from Google Earth (GE), impervious surface derived from Landsat satellite image, and distance from water channel. Google Earth DEM was obtained from Google Earth image through GPS Visualizer link http://www.gpsvisualizer.com/convert_input free-of-charge. Besides its 3D mapping of the globe, GE also has the capability of providing elevation data obtained by Shuttle Radar Topographic Mission (SRTM) [21]; [22]; [23]. The choice of GE was it accuracy level and that of being free to all users. The work of [24] had shown that GE accuracy is acceptable for most applications. The regular updating of GE data has also improved the accuracy of elevation data.

Landsat data used in deriving impervious surface was downloaded free-of-charge from the website http://glovis.usgs.gov by complying with the downloading procedures. The image was downloaded in zip using path 188 and row 57. The downloaded was the precision orth-corrected product (LIT) which has been corrected for both radiometric and geometric distortions [25]. Landsat 8 (L8) acquired 18/2/2021 with 30m x 30m spatial resolution was used for the study. L8 used improved sensor called Operational Land Imager (OLI) [26] for earth's observations. L8 was launched into space in 2013 with the sensor having eleven (11) spectral bands [27]. The mission was aimed at improving on the spectral resolution of earth's surface feature for effective environmental mapping.

Rainfall data was obtained from satellite (EUMESAT) derived by Tropical Applications of Meteorology using Satellite data and ground-based observations (TAMSAT). The university-based team of scientists from the University of Reading established TAMSAT in 1980 [28]. The mandate was to use satellite to estimate rainfall and other surface water budget for the whole of Africa. TAMSAT data was selected for the flash flood mapping because it spatial variations can be obtained. However, NiMET reported precipitation data were used to validate satellite derive rainfall data.

Water channel was extracted from the orthophoto of Port Harcourt city. Orthophoto was obtained from the Office of the Surveyor General Rivers State (OSGRV).The channel was also validated by conducting on-site observations using GARMIN 76SCx hand held global positioning system receiver. Table 1 summarized the characteristics of data used in flash flood analysis.

Table 1 Summary of datasets used in flash flood risk analysis

S/N	Data	Date	Source
1	Landsat 8	28/02/2017	http://glovis.usgs.gov/
2	DEM	NA	Google Earth
3	Water Channel	NA	OSGRV
4	Rainfall	20/09/2020	http://www.tamsat.org.uk

ESRI's ArcGIS 10.3.1 was used to performed NDVI, MCA analysis, and map compilations.

2.2 Data Processing

Data processing is required for any flash flood modeling. It was performed on each dataset used in the study and they are

2.2.1 Slope Model

Slope model is an integral factor in flash flood analysis. Slope model depicts physical terrain surface including ridges, valleys and flat surfaces. Terrain steepness can be expressed in degrees or as a percentage [29]. Slope of an area determine the intensity of flash flood but the fatalities increase with steepness [30]. In general, flash flood risk increases on flat slope [31], this is because, flat terrain allows rainwater to accumulate. Google Earth digital terrain model (GEDEM) was used to produce slope model in ESRI's ArcGIS.

2.2.2 Impervious Surface

A major problem in most urban areas is surface imperviousness. It resulted from the construction of roads, bridges, parks etc. and also a direct consequence of urbanization. In addition, the surface is covered by impermeable objects [32] which hold the water from infiltrating the soil. Impervious surface influences flash flood occurrence and risk in an area. Risk associated with flash flood increase with the increase in surface imperviousness. Surface imperviousness was derived from Landsat 8 using NDVI analysis. [33] Also used NDVI to derived impervious surface in Bhopal city of Pradesh. Prior to NDVI analysis, the raw image (DN image) was converted to radiance using the formula;

$$L_\lambda = ML_x Q_{cal} + A_L \qquad 1$$

Where,
L_λ = spectral radiance in $Wm^{-2}Sr^{-1}$
M_L = radiance multiplicative scaling factor for the band
Q_{cal} = L1 pixel value in DN and
A_L = radiance additive scaling factor for the band [34].

The values of the parameters for the bands are stated in the Landsat 8 metadata file.

The computed radiance image was used in the computation of NDVI. NDVI equation is given by

$$NDVI = (NIR - RED)\ (NIR + RED) \quad 2$$

The value ranges from 1 to -1 and values below 0.1 are barren land while values from 0.2 – 0.3 are grassland. Flash floods risk is suppose to be high in barren or built-up areas than areas with grassland or shrubs. Barren land and built-up created compacted surface which prevent rain water from easily infiltrate, resulting to flash flood.

2.2.3 Precipitation

Another critical factor in flash flood risk modeling is precipitation. Intensity of precipitation defers from place to place and so its impacts defer. During precipitation, the absorbing capacity of the soil will be exceeded and when the soil could not absorb water, surface run-off occurred as flash flood. Spatial distribution of rainfall was obtained from georectified TAMSAT data.

2.2.4 Distance to Water Channel

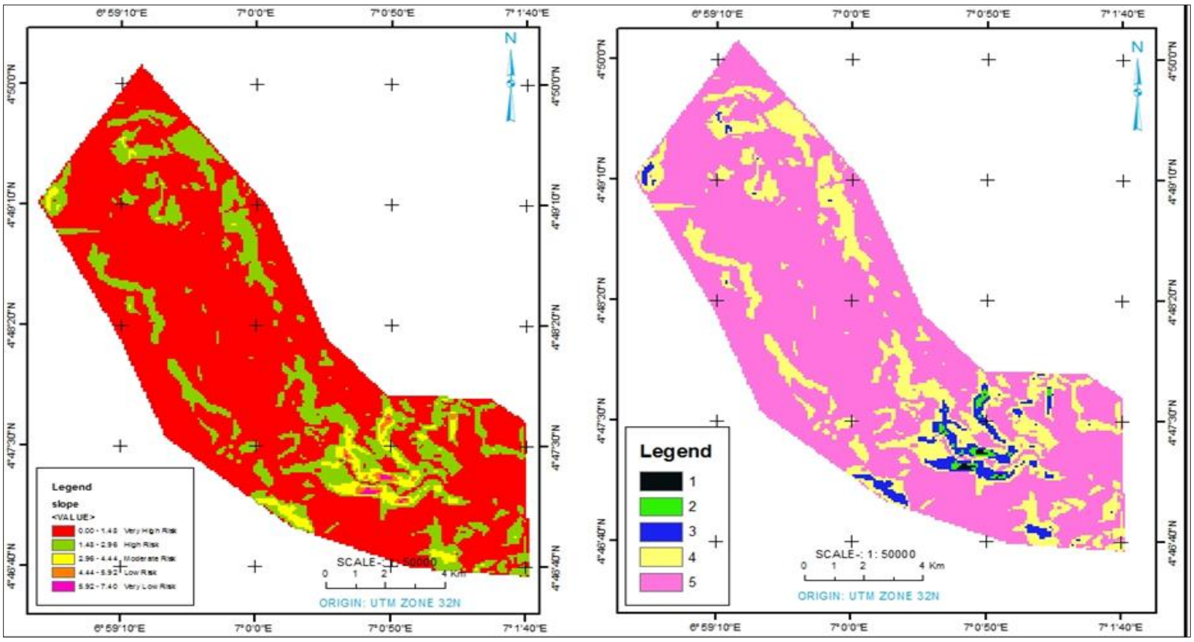
Flash flood risk increase in areas close to water channels. The risk decreases as the distance from the river increases. River channels were extracted from orthophoto from which Euclidian distance was computed. Euclidean distance uses straight line distance to calculate each cell's relationship to a source or a set of sources. [35] used buffer analysis to calculate distance from the main river channels for flood risk modeling in India.

2.3 Multi-Criteria Analysis

Multi-Criteria Analysis (MCA) enables us to make accurate and reliable decision that will solve a host of environmental problems. Decisions to solve complex problems can be made by an individual or an organization [36]. MCA is a tool that aids decision makers in arriving at solutions to complex problems [37]. In spatial analysis, the main elements of MCA are scaling, criteria weighting and decision.

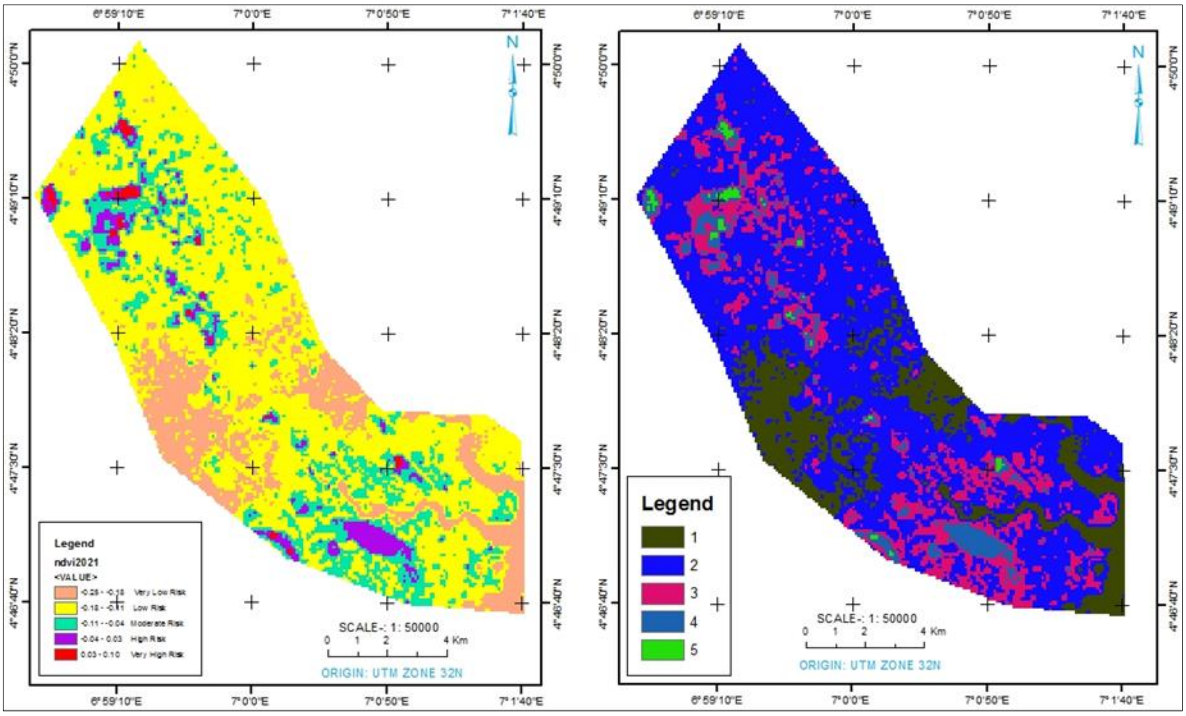
Modeling flash flood risk is one of such complex problems that involve combination of criteria. The criteria are slope model, impervious surface, precipitation, and distance to water channel. Each criterion in the model were reclassified and scaled from 1 to 5, with 5 represents highest risk and 1 represents lowest flash flood risk area. Other three score range was scale in between 5 and 1. The study adopted ranked method to weight the criteria due to its simplicity [36]. In MCA, criteria weights are sum to 100 for complex decision to be effective.

3. Results and Discussions



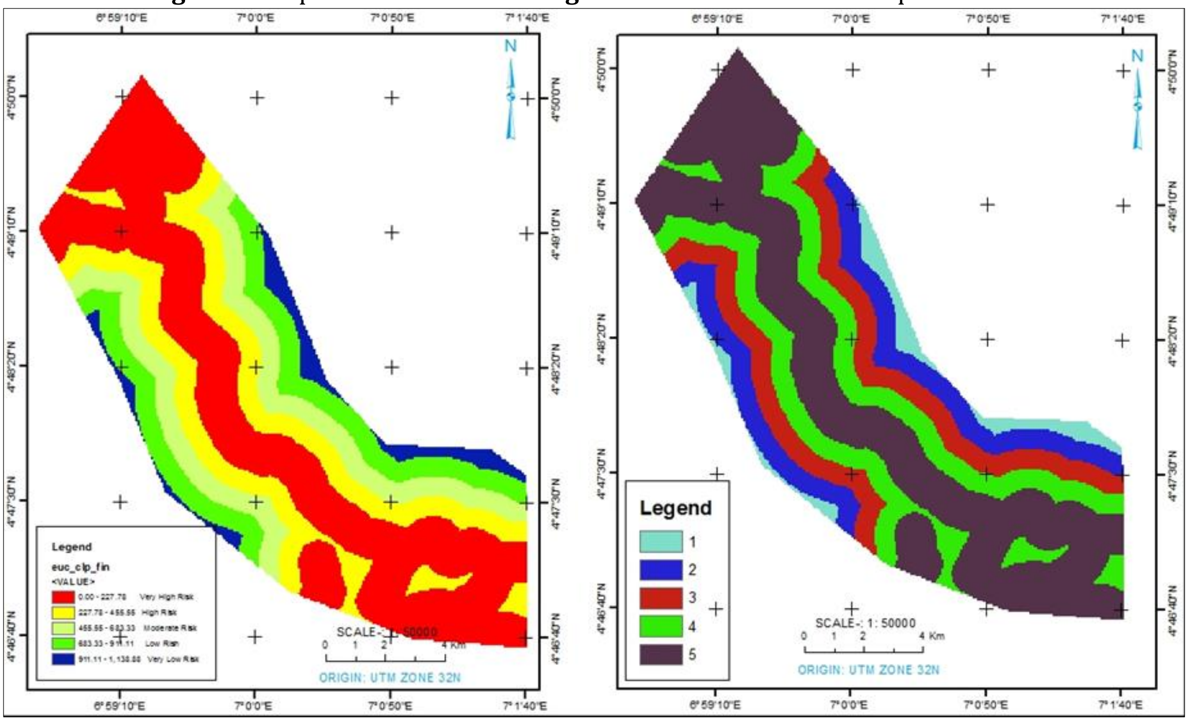
(3a) (3b)

Figure 3 a Slope model and **Figure 3b** is the reclassified slope model



(3c) (3d)

Figure 3c Impervious surface and **Figure 3d** is the reclassified impervious surface



(3e) (3f)

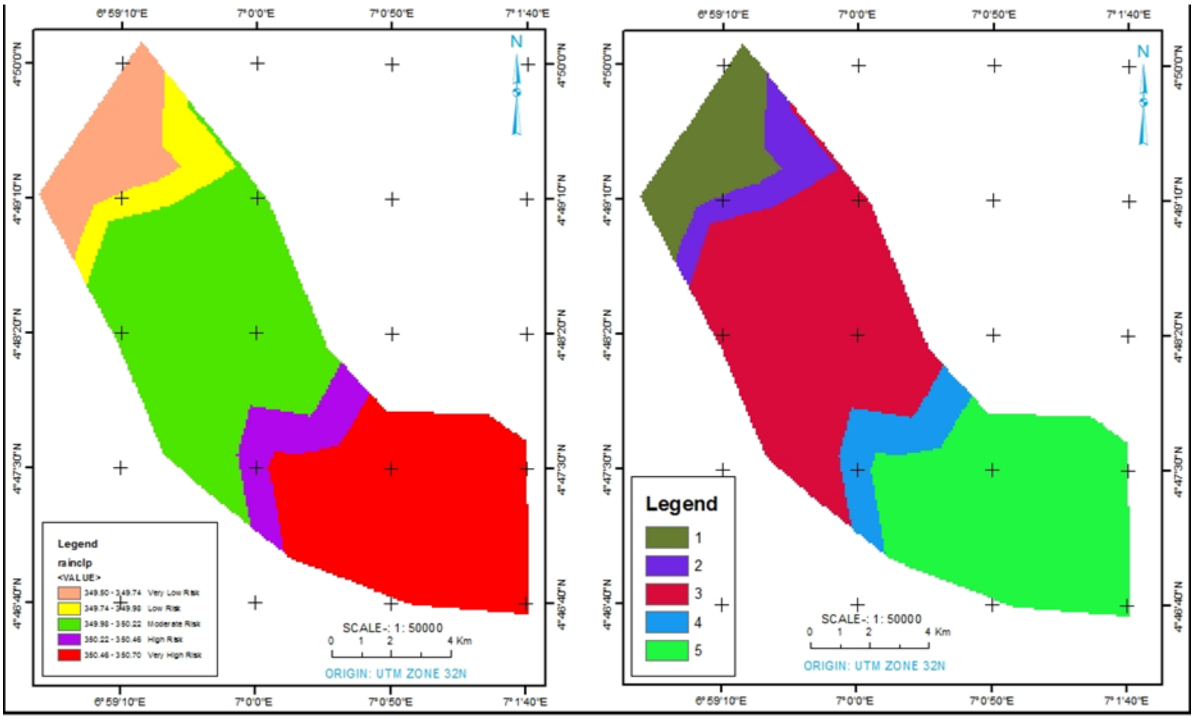
Figure 3e and 3f are the Euclidean distance and reclassified Euclidean distance

The reclassified slope model represented in degree of slope varies from 0.00° lowest to 7.40° highest slope value. The scale (5 to 1) was assigned to the score range according to their risk level. Score range of 0.00° - 1.48° was scale 5 because is the lowest slope, hence, highly vulnerable to flash flood. Also, range of 1.48° - 2.96° was scale 4, being high flash flood risk slope. The lowest risk area ranges from 5.92° – 7.40° with scale of 1. Figure 3.1a and 3.1b display slope and reclassified map used in flash flood analysis.

Similarly, impervious surface derived from NDVI was also scaled and the value varies from –lowest 0.25 to highest 0.10, indicating lack of vegetation. Score range 0.03 – 0.10 with scale 5 was the high risk flash flood locations. They are the built-up areas with compacted surfaces. The last range was from -0.24 - -0.18 with scale 1, comprises of water bodies, mainly saltwater with no or little flash flood risk. Other score ranges were scaled in between 5 and 1.Impervious surface of the area is shown in figure 3.1c and 3.1d.

Accordingly, the reclassed Euclidean distance varies from 0.00m to 1139m and their ranges where scaled. Score range 0.00m – 278m was assigned scale of 5 being high flash flood risk areas. The second class was with score 278m – 456m with scale 4. The last and the lowest risk area ranged from 911m – 1139m with scale 1. The assumption was base on the fact that flash flood risk is base on proximity to water sources. Hence, the closer the area to water body, the more susceptible they are. Figure 3.1e and 3.1f depicts Euclidean distance and the raclassed data used in the analysis.

Figure 3.1g and 3.1h are the spatial variations of precipitation and the reclassified used in flash flood modeling. It ranges from minimum 349.50mm to 351.70mm. High rainfall value was assigned to highest scale 5 and lower rainfall to lowest scale 1. Score range 350.46mm – 350.70mm was assigned scale of 5, being high flash flood risk areas. The last score range 349.50mm – 349.74mm was assigned scale 1, being least risk locations to flash flood. Flash flood disaster increased with increase in rainfall intensity.



(3g) (3h)

Figure 3g and 3h are the spatial variation of rainfall and reclassified data

These criteria were assigned weights, which specify importance of one criterion relative to others [36]. Weights are based on assumption of the decision makers but guided by the preference of criteria. Here, distance to water channel was assigned weight of 48, impervious surface 25, slope model, 22 and rainfall 5. It was summed to 100 percentage influence as required for the MCA. Table 3.1 provided the scale and weight used in the analysis.

The criteria were combined in weighted overlay tool in ArcGIS Spatial Analyst Tools to produce flash flood risk map (FFRM) as shown in figure 3.1i. The risk map reveals that only 6 percent of the study area was within very high risk with an area of 93ha. [38] in their study in Sudan observed that very high risk due to flash flood covered 73.50ha of land representing 11.92 percent of the area. Very high risks are mostly located along the water channels of Ntawogba Creek. Some sections of Ameachi and Olu Obasanjo Road along the creek were located in the very high risk zones. Other locations situated in the very high risk zones are Gulf Club, Winner Chapel, Head Quarters of Federal Road Safety Corps (FRSC) at PH/ Aba Express Road, and Sani Abacha Road. The results of the analysis of this study agreed with the flash flood events that occurred in July 2017. This flash flood affected FRSC office located in PH/ Aba and spread to entire Dline, Port Harcourt [39]. Also, collaborating the study analysis was the flash flood of September 22, 2021 in Port

Harcourt that affected FRSC and the stretch of Dline [40]. Other locations affected by the flash flood are Sani Abacha road, Olu Obasanjo road, Ameachi Road and many homes submerged by floodwater. The flash flood was as a result of 10hours downpour, and was seen as the heaviest downpour in the year 2021.

Table 3 Summarized the scale and weight used in flash flood analysis

S/n	Criteria	Range & scale		Flood risk	Weight
1	Rainfall (mm)	350.46 – 350.70	5	Very High	5
		350.22 – 350.46	4	High	
		349.98 – 350.22	3	Moderate	
		349.74 – 349.98	2	Low	
		349.50 – 349.74	1	Very Low	
2	Slope (°)	0.00 – 1.48	5	Very High	22
		1.48 – 2.98	4	High	
		2.96 – 4.44	3	Moderate	
		4.44 – 5.92	2	Low	
		5.92 – 7.40	1	Very Low	
3	Impervious Surface	0.03 – 0.10	5	Very High	25
		-0.04 - 0.03	4	High	
		-0.11 – -0.04	3	Moderate	
		-0.18 – -0.11	2	Low	
		-0.25 – -0.18	1	Very Low	
4	Distance to River (m)	0.00 – 227.78	5	Very High	48
		227.76 – 455.55	4	High	
		455.55 – 683.33	3	Moderate	
		683.33 – 911.11	2	Low	
		911.11– 1138.88	1	Very Low	

The second class was the high flash flood risk with total area 864.1ha, represented with light blue. High risk zones occupied 56.0 percent of the area and lied along Ntawogba Creek. These locations also suffered from flash flood of September 22, 2012 and other floods in the city. The third class was the moderate flash flood risk zones. This covers total area of 452.2ha representing 29.3 percent of the study area. It is about 0.85km from Ntawogba Creek. The last class was the low risk zone, located about 1.1km from the Ntawogba Creek. Part of Diobu is within this zone and they experienced lesser flash flood risk. The zone is represented with green and occupied the extreme map locations. Flash flood of September 22, 2021 has the least impact in Diobu because of the high elevation and good drainage network that discharged rainwater to the salt water of Diobu River. [41] Also observed lesser flash flood impacts on areas with high elevation in Abidjan District, Cote D'Ivoire. High elevation increase runoff rate of flood water to nearby reservoirs. Table 3.2 shows total area in hectares (ha) of each flash flood risk zones.

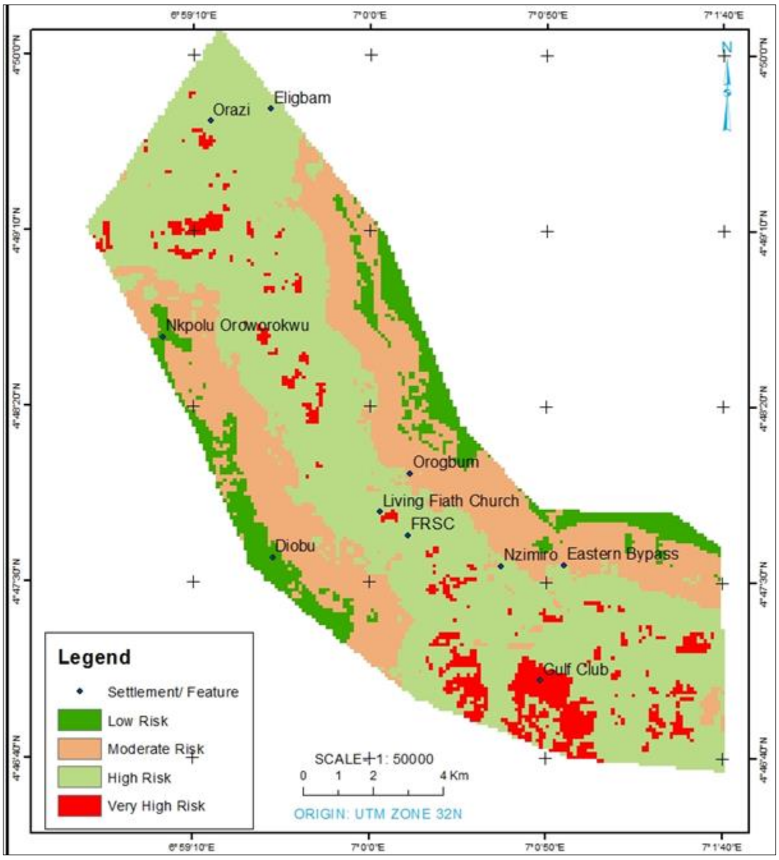


Figure 3i Flash flood risk map

Table 2 Total area of each flash flood risk zones

CLASS	AREA (ha)	% AREA
Low	134.7	8.7
Moderate	452.2	29.3
High	864.1	56.0
Very High	93.0	6.0
Total	1544	100

The total percentage of area in the table was 100. By combining very high and high risk, total area will be 957.1ha with percentage of 64. This shows that greater percentage of the study area is at risk of flash flood disaster.

4. Conclusion

Flash flood is that type of flood that occurs within 6hours of rainfall event and occurs mostly in urban areas without proper drainage systems. It destroyed houses, communication networks, roads, recreational centers, schools, hospitals, etc. The application of remote sensing and GIS has improved the mapping of flash flood risk areas. Flash floods vulnerable and risk zones have been mapped using AHP and other proximity analysis like buffer. There was little knowledge about the applications of direct ranking methods to weight criteria which has been considered appropriate for few criteria. Hence the main objective of this study was to apply MCA direct ranking method to mapped flash flood risk zones in a section of Ntawogba Creek, Port Harcourt. Four criteria were scaled from 5 to 1 and weight assigned according to how importance in the decision making process. Scale 5 implies very high flash flood risk while scale 1 presents very low risk. Integrating the criteria using weighted overlay tool in Arc GIS, potential risk zones was mapped.

The study observed that very high and high risk zones agreed with the flash floods of July 29, 2017 and September 22, 2021 in Port Harcourt.

Recommendation

For further study, it is recommended that drainage density of each basin should be included in flash flood risk analysis. Drainage density is the total length of channels within the basin divided by area of the basin [18]. Including soil infiltration rate could have further improved the accuracy of the results, further study should considered infiltration rate in the decision making. Infiltration rate was not considered in this study due to homogenous soil in the area. The major limitation of this work was lack of NiMET reported rainfall data that can show exact spatial variations of rainfall in the area. The study adopted satellite derived rainfall which is generalized data.

Compliance with ethical standards

Disclosure of conflict of interest

The authors involved in this article have unanimously agreed and declared that no conflict of interest with any person or organization.

References

[1] National Weather Service. Floods the Awesome Power, U.S Department of Commerce, National Oceanic and Atmospheric Administration. 2010; 1- 16.

[2] Environment Agency. Groundwater Flooding Brief Notes, Kent County Council. 2014; 1-4.

[3] Thurston County Emergency Management. Groundwater Flooding Information. 2011; 1-2.

[4] Leal M, Ramos C. The Potential of Two Types of Urban Flooding to Caused Material Damages in Lisbon, Portugal, Int. J. of Safety and Security Eng. 2017; 7(2): 190-200.

[5] Jha AK, Robin B, Jessica L. Cities and Flooding, A Guide to Integrated Urban Flood Risk Management for the 21st Century, The World Bank, 1818 H Street NW, Washington DC 20433. 2012; 57-65.

[6] NOAA. Flash Floods and Floods, the Awesome Power, a Preparedness Guide. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service. 1992; 1-12.

[7] USDA. Know before you go preparing to Visit a National Forest. 2010; 1.

[8] Menne B, Murray V.(Ed.). Flood in the WHO European Region Health Effects and their Prevention, WHO Regional Office for Europe, UN City, Marmorvej 51, DK-2100 Copenhagen O. Denmark. 2013; 7.

[9] Mohamed A, Worku H, Sterk G. Urban Land Cover and Morphometric Analysis for Flash Flood Vulnerability Mapping, and Riparian Landscape Conservation in Kebena River Watershed, Addis Ababa 2012; 1-17.

[10] National Weather Service. Floods the Awesome Power, U.S Department of Commerce, NOAA's National Weather Service. 2005; 1-16.

[11] Ashley ST, Ashley WS. Flood Fatalities in the United States, American Meteorological Society. 2008; 806-818.

[12] Alipour A, Ahmadalipour A, Moradkhani H. Assessing Flash Flood Hazard and Damages in the Southeast United States, J. Flood Risk Management. 2020; 1-17.

[13] Wang Y, Colby JD, Mulcahy KA. The efficient Method for Mapping Flood Extent in a Coastal Floodplain Using Landsat TM and DEM Data, INT. J. Remote Sensing. 2001; 23(18): 3681-3696.

[14] Ho LTK, Umitsu M, Yamaguchi Y. Flood Hazard Mapping by Satellite Images and SRTM DEM in the Vu Gia – Thu Bon Alluvial Plain, Central Vietnam, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, Volume XXXVIII, Part 8, Kyoto Japan. 2010; 275-280.

[15] Lawal DU, Matori AN, Yusuf KW, Hashim AM, Balogun AL. Analysis of the Flood Extent Extraction Model and the Natural Flood Influencing Factors: A GIS-based and Remote Sensing Analysis, 8th International Symposium of the Digital Earth (ISDES), IOP Conf. Series: Earth and Environmental Science. 2014; 18: 1-6.

[16] Mohamed A, Worku H, Sterk G. Urban Land Cover and Morphometric Analysis for Flash Flood Vulnerability Mapping, and Riparian Landscape Conservation in Kebena River Watershed, Addis Ababa. 2020; 1-12.

[17] Sadek M, Li X. Low-Cost Solution for Assessment of Urban Flash Flood using Sentinel-2 Satellite Images and Fuzzy Analytical Hierarchy Process A Case Study of Ras Ghareb City, Egypt, Advances in Civil Engineering. 2019; 1-16.

[18] Elkhrachy I. Flash Flood Hazard Mapping using Satellite Images and GIS Tools: A Case Study of Najran City, Kingdom of Saudi Arabia (KSA), The Egyptian Journal of Remote Sensing and Space Sciences. 2015; 18: 261-278.

[19] National Bureau of Statistics. Annual Abstract of Statistics, Federal Republic of Nigeria. 2010; 4.

[20] NiMET. Agrometeorological Bulletin No. 8, Dekad 2, March (11-20) 2018; 1-3.

[21] El-Ashmawy K. Investigation of the Accuracy of Google Earth Elevation Data, Artificial Satellites. 2016; 51(3): 89-97.

[22] Wei H, Luan X, Li H, Jia J, Chen Z, Han L. Elevation Data Fitting and Precision Analysis of Google Earth in Road Survey, AIP Conference Proceedings. 2018; 02003: 11-9.

[23] Sharma A, Gupta D. Derivation of Topographic Map from Elevation Data available in Google Earth, Civil Engineering and Urban Planning: An International Journal (CiVEJ). 2014; 1(1): 14-21.

[24] Hoffmann E. Generating High-Resolution Digital Elevation Models for Wetland Research using Google Earth (TM) Imagery- an Example from South Africa, water. 2010; 1-24.

[25] USGS. Product Guide Landsat 4-7 Surface Reflectance (LEDAPS) Product, Version. 2017; 7(6): 1-35.

[26] Zhu L, Suomalainen J, Liu J, Hyyppa J, Kaartinen H, Haggren H. A Review: Remote Sensing Sensors. 2018; 19-42.

[27] USGS. Landsat 8 (L8) Data Users Handbook Version 5.0, Department of Interior, U.S. Geological Survey. 2019; 1-114.

[28] University of Reading. TAMSAT Data Policy. 2017; 1-3.

[29] Heywood I, Cornelius S, Carver S. An Introduction to Geographic Information System, 3rd Edition, Pearson Education Limited, Edinburgh Gate Harlow Essex CM20 2JE England. 2006; 203: 77 – 91.

[30] Disaster Summary Sheet. Floods. 2012; 1-23.

[31] Njoku CC, Efiong J, Ayara NN. A Geospatial Expose of Flood-Risk and Vulnerability Areas in Nigeria, International Journal of Applied Geospatial Research. 2012; 11(3): 1-25.

[32] Kent BB, John MM, Martin CR. Impervious Surfaces and the Quality of Natural and Built Environments, Department of Geography and Environmental Planning, Towson University, 8000 York Road Baltimore, Maryland 21252-0001. 2002; 1-28.

[33] Dhivya B, Niranjan SS, Sarup J, Dharavath K. Mapping of Impervious Surface using Spectral Angle Mapper (SAM) and NDVI Techniques, Case Study: Bhopal City, Indian Journal of Science and Technology. 2015; 8(28): 1-6.

[34] USGS. Landsat 8 (L8) Data Users Handbook, Version 2.0, Department of the Interior, U.S. Geological Survey. 2016; 9.

[35] Baishya SJ, Sahariah D. Application of Remote Sensing and GIS for Flood Hazard Mapping: A Case Study at Baralia-Nona River Basin, Assam, India, International Journal of Humanities and Social Science Innovation (IJHSSI) ISSN (Online). 2017; 5(3): 58-70.

[36] Malczewski J, Rinner C. Multicriteria Decision Analysis in Geographic Information Science, Advances in Geographic Information Science. 2015; 23.

[37] Lesslie RG, Hill MJ, Hill P, Cresswell HP, Dawson S. The Application of a Simple Spatial Multi-Criteria Analysis Shell to Natural Resource Management Decision Making. In: Pettit C., Cartwright W., Bishop I., Lowell K., Pullar D., Duncan D. (eds) Landscape Analysis and Visualisation. Lecture Notes in Geoinformation and Cartography. Springer, Berlin, Heidelberg. 2008.

[38] Hamid HTA, Wenlong W, Oiaomin L. Environmental Sensitivity of Flash Flood Hazard using Geospatial Techniques, Global J. Environ. Sci. Manage. 2020; 6(1): 31-46.

[39] Leadership New Paper. Rage of Prot Harcourt Creeks. 29 July 2017.

[40] Vanguard. FRSC, SPAR, Homes take the Heat as Heavy Rains Submerge Port-Harcourt. 2021.

[41] Danumah JH, Odai SN, Saley BM, Szarzynski J, Thiel M, Kwaku A, Kouame FK, Akpa LY. Flood Risk Assessment and Mapping in Abidjan District using Mul-ticriteria Analysis (AHP) Model and Geoinformation Techniques, (Cote d'Ivoire), Geoenviromental Disaster. 2016; 3(10): 1-13.