FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 5 No. 1, March, 2021, pp 1 – 10
DOI: https://doi.org/10.33003/fjs-2021-0501-533

DELINEATION OF URBAN FLOOD RISK AREAS USING GEOSPATIAL TECHNIQUE

Sulaiman Yunus

Department of Geography, Bayero University Kano

Email: syunus.geog@buk.edu.ng

ABSTRACT

The threat posed by urban flooding in most cities of the world is becoming alarming especially within the recent decades. This makes it necessary to Identify and delineate flood risk areas within cities in order to curb it menace. This study employs geospatial technique to delineate flood risk areas within Kano metropolis with a view to mitigating its impact on lives and properties. Digital Elevation Model (ASTER DEM 30m) was used to derive excess surface run-off attributes including flow direction and accumulation. Based on these attributes, flood risk areas were determined and delineated using buffer distances of 500 meters. World View image (30 cm spatial resolution) was used to identify the landuses at risk. The result from the analysis delineated flood risk areas at varying exposure levels (i.e high, moderate and low).It was evident that flood risk level within the metropolis corresponds to the pattern of surface run-off flow accumulation areas. Settlements and farmlands found within high accumulation areas along the floodplains of River Jakara (in the North and North-eastern part) and Kano-Zaria road (southern part) are at higher risk than those found on low accumulation areas. The study concluded that excess surface run-off flow direction and accumulation are among the fundamental factors determining the risk to urban flooding. The study recommends that with the ongoing level of urban development and impervious surface expansion, urban planners and policy makers should make use of the flow direction and accumulation maps in determining safer places for future developments.

Keywords: *Digital Elevation Model, Flow Direction, Flow Accumulation, Buffer Analysis.*

INTRODUCTION

Flood is one of the most recurring and devastating hazards affecting human lives and causing severe economic damage throughout the world, (Khan *et al*, 2011). Studies have predicted that with the prevailing climate variability, flood intensity and frequency will threaten many regions of the world in the future (Jonkman & Dawson 2012). Floods occur because of the rapid accumulation and release of runoff waters from upstream to downstream, which is caused by very heavy rainfall. Urbanization due to population increase results into conversion of agricultural land and natural vegetation/wetlands into built-up environments thereby increasing the amount of excessive surface run-off which accumulates on the lower lands (Nuissl and Siedentop (2021). This scenario implies that urban areas in particular suffer from a comparatively high flood risk due to their high population number and density, multiple economic activities and many infrastructure and property values, which in turn interferes with the natural infiltration processes. The rate of recurrence of urban flooding is of great concern due to the number of lives affected and properties destroyed globally (Borga et al., 2014 and Simonovic, 2011). Flood vulnerability is expected to increase in frequency and severity, due to urbanization and climate change, severe weather in the form of heavy rains and river discharge conditions (Dihn, Balica, Popescu & Jonoski 2014). The current trend and future scenarios of flood risks therefore demand for accurate spatial and temporal information on the potential hazards and risks of floods.

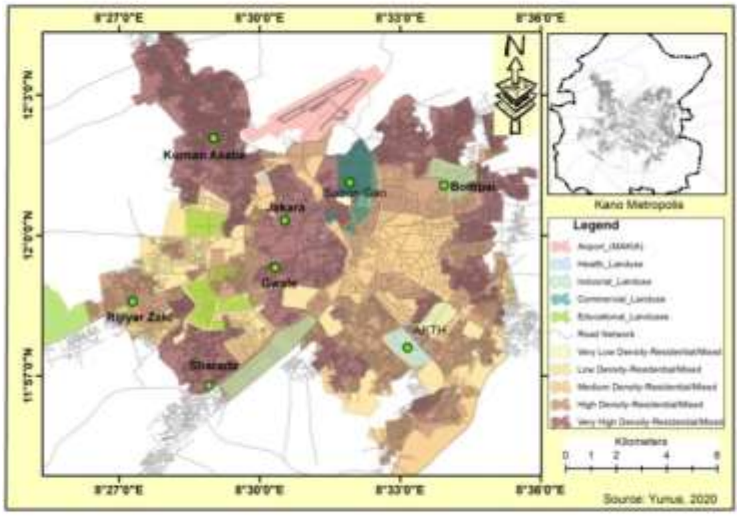
With the rapid development of urbanization, flood risks become more and more severe (Dawson, 2008). With the continuous expansion of cities, the urban flooding and waterlogging problems areexpected to become worse and worse unless more effective measures are adopted. However, flood risk assessment in urban areas is more complex than in rural areas because of their closely packed buildings, different kinds of land uses, and large amounts of flood control works and drainage systems Cheng and Li, (2015). Risk assessment is an essential component of sustainable urban flood management and is becoming more important with the increase in population density and the intensifying effects of climate change.In urban flood risk analysis uncertainty is mainly associated with spatial and temporal variability in urban stormwater hydrology, which includes variables such as precipitation; drainage area size, shape and orientation; ground cover and soil type; slope of terrain; vegetation; roughness; porosity; storage potential(wetlands, ponds, reservoir etc.); characteristicsof drainage system, etc. Depending on the spatial and temporal variability of rainfall intensity, rainfall duration and direction of storm movement there can be wide range of shapes of rainfall hyetographs Cheng and Li, (2015).

Flood menace in Nigeria remains one of the most frequent and widespread hazards in the built environment as it can simultaneously affect agriculture, settlement, flora and fauna, transportation, education, food security, infrastructure, peace building among others (Grothman, 2017; Ikusemaran, 2017;Agbonkhese et al., 2014; Percival and Teuw, 2019). The widespread effects of floods as reflected in the 2030 Agenda for Sustainable Development (ASD) linked the disaster to one of the challenges limiting sustainability (UN Habitat, 2019). Several studies have been conducted locally and globally on flooding using various approaches and techniques of data analysis. Most of these studies focused on the use of geospatial, statistical and mixed methods in analyzing qualitative, quantitative and remotely sensed data types to examine flood vulnerability, risk, assessment of impact and flood prediction and modeling. For example, studies byAlfieri et al., (2012); Rozalis et al., (2010); Biondi et al., (2013); Seal et al., (2012); Raha et al., (2012); Dawod et al., (2011a); Samarasinghe et al., (2010); Al Saud, (2010); Hailian et al., (2010); Zhang et al., (2010); Xiaomeng et al., (2011); Liu et al., (2011); Sulaiman et al., (2012) ;Chan et al., (2011); Dawod et al., (2011b); Ojigi, Abdulkadir & Aderoju, (2013); Daffi, Okun & Ismail, (2014); Nwilo *et al*. 2012; Ogwuche & Abah, (2014); Ejikeme *et al*. (2015); Nabegu, (2014); Bamidele and Badiora (2019); Agbonkhese et al.,(2014); Ilyasu, (2017); Azua et al.,(2019) and Nkwunonwo (2015); Adelekan, 2010;Emmanuel, 2016; Eze, Vogel and Ibrahim, 2018; Itopa, 2018; Ikusemanran among others have done so much with regards to flood disaster. However, this particular study is different from most of the afore mentioned in terms of the approach and method of flood risk delineation adopted. Flood risk analysis is more complex in urban areas than that in rural areas because of their closely packed buildings, different kinds of land uses, and large number of flood control works and drainage systems. This study aimed at delineating urban flood risk areas within Kano metropolis based on the analysis of excess surface run-off flow direction and accumulation. This is to enable taking policy and practice measures in order to reduce the risk to urban flooding and mitigate it impact for sustainable urban development.

STUDY AREA

Geography and Location

Kano metropolis is located between longitudes 8^0 25' E to 8^0 40' E and latitude 11^0 50' N and 12^0 10' N. The metropolis comprises of eight (8) local government areas (Dala, Fagge, Gwale, Kano Municipal, Nassarawa, Tarauni) and parts of Kumbotso and Ungoggo (Maigari, 2014). It covers the total built-up area of about 238.42km^2 as at 2018 (Figure 1). The population of the metropolis is projected to about 4, 008, 306 (populationstat.com, 2020). The area has in recent years undergone rapid growth and transformation which is accompanied by increase in intensities of human activities, landuse conversion, convergence and dynamics of social and environmental risks and disasters (Barau *et al.* 2015).



Source: Yunus, 2020

Figure 1: Showing Kano Metropolis

Weather and Climate

The metropolis is characterized by semi-arid type of climate with daily mean temperature of about 30^{0}C. Lowest temperatures i.e 20^{0}C is recorded between December and February (Tanko and Momale, 2014). The climate is characterized by two main seasons; the wet rainy season occurring around May- October, and the dry season occurring between November and April. The climate is the tropical wet and dry type coded as Aw by Koppen‘s classification of climate. The rainfall regime is such that the amount is highest in the south (1200mm/annum) and decreases northward to less than 884mm/annum.

Environmental Hazards and Disasters

There has been increase in the rate of rural-urban migration, illegal and unplanned settlement, built-up areas, air and noise pollution, outbreaks of fire disaster, biodiversity depletion, contamination of wells and surface water bodies, disappearing open spaces, recurring of flooding, poor sanitation, and modification of urban micro climate (Bichi, 2000; Maiwada, 2000; Barau 2007; Nabegu, 2010; Dankani, 2013; Ali and Young, 2014; Maigari, 2014; Butu and Mshelia, 2014; Isah, 2015). The threat of urban flooding is a serious problem in the metropolis with many homes and streets inundated with water especially during the rainy season. This makes efforts towards mitigating the impact a major concern to urban planners, policy makers, researchers and other stakeholders.

RESEARCH METHODS

This section describes the data types, sources, and analyses methods adopted for urban flood risk analysis within Kano metropolis. Figure 2 presents a flow chart that summarizes the data types and methods of analyses conducted in this study.

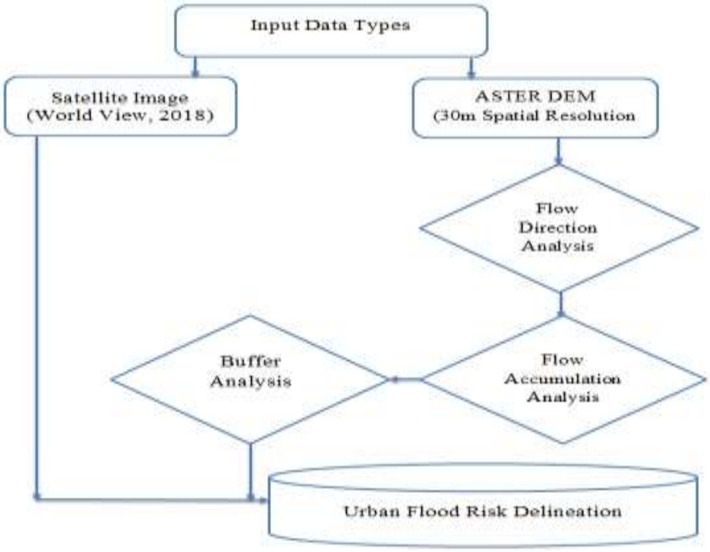


Figure 2: Methodological Flow Chart

Data Types and Sources

The data used for urban flood risk analysis in this study are largely Raster data in the form of Digital Elevation Model (ASTER DEM) with 30m spatial resolution and World View satellite image of 2018 (30 cm spatial resolution). The ASTER DEM was downloaded from the official website of United State Geological Station (USGS), http://earthexplorer.usgs.gov, and was used to derive the terrain model of the study area. Surface Hydrological analyses such as Fill, Flow Direction and Flow Accumulation were performed using the DEM. The satellite image on the other hand is sourced from the Kano Geographical Information System Department (KanGIS) of the ministry of land and was used to depict the households at risk within the defined buffer distances at various levels of accumulation.

Data Analyses Methods

The data analyses conducted to determine urban flood risk within Kano metropolis includes: Surface Flow Direction, Surface Flow Accumulation, Spatial Query(using Raster Calculator) and Buffer analysis. These were to provide an understanding of the relationship between the nature of a terrain (elevation and slope) and risk to flooding in urban areas. These analyses enable identification of flood risk areas based on the direction of flow of excess run-off water especially during rainfall and areas/amount of accumulation. Buffer analysis defines areas of risk at certain distance from accumulation areas at various levels.

Surface Flow Direction Analysis

In order to determine urban flood risk areas, flow direction analysis (used for deriving hydrologic characteristics of a surface) was conducted using the ASTER DEM (30m spatial resolution) to create a raster output showing the direction of flow of excess run-off during rainfall from each cell to its steepest downslope neighbor. This is done with the Flow Direction tool (ArcGIS 10.2) which takes a surface data (DEM) as input and outputs a raster showing the direction of flow out of each cell. The direction of flow is determined by the direction of steepest descent, or maximum drop, from each cell which is calculated as follows:

Maximum Drop = Change in Z-Value (elevation) / Distance * 100

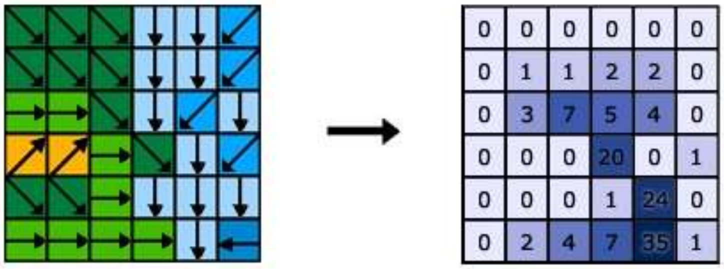
The distance is calculated between cell centers, and therefore, if the cell size is 1, the distance between two orthogonal cells is 1, and the distance between two diagonal cells is 1.414 (the square root of 2). On the other hand, if the maximum descent to several cells is the same, the neighborhood is enlarged until the steepest descent is found. When the direction of steepest descent is found, the output cell is coded with the value representing that direction. This study adopted the eight-direction (D8) flow model approach (Jenson and Domingue, 1988) which identifies eight valid output directions relating to the eight adjacent cells into which flow could travel. The directions of excess run-off flow and the coding (especially during rainfall) using flow direction analysis are illustrated in Figure 3.

Figure 3: Flow Directions and Codes

Figure 3 especially based on the nature of the terrain gives an insight on the overall flow direction pattern, thereby enabling detection of run-off accumulation areas. For the sake of this particular study, the coding of the flow direction is substituted with the cardinal directions (i.e 64 = N, 4 = S, 1 = E, 16 =W, 128 = NE, 2 =SE, 8 = SW and 32 = NW). This is to enable easy interpretation of the flow direction map.

Surface Flow Accumulation Analysis

After conducting surface flow direction analysis to appreciate the nature of the terrain and understand the direction of flow of excess run-off water especially during rainfall, surface flow accumulation analysis was then conducted using the DEM to createa raster output describing the accumulated flow into each cell. The Flow Accumulation tool (ArcGIS 10.2) calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell. Cells with a high flow accumulation are areas of concentrated flow and may be used to identify stream channels (ESRI, (2020). Cells with a flow accumulation of 0 are local topographic highs and may be used to identify ridges.This in other words signifies that, the higher the accumulation flow value, the lower the elevation and the less steep is the slope and vice versa. In order to depict the relationship between flow direction and accumulation, figure 4 clearly shows the direction of travel from each cell and the number of cells that flow into each cell (accumulation).This method of deriving accumulated flow from a DEM is also presented in Jenson and Domingue (1988).



0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	1

Figure 4: Flow Direction and Accumulation Relationship

Raster-Based Spatial Query Analysis

In order to determine accumulation zones at various levels across the metropolis, flow accumulation was reclassified into three different classes based on the weight of accumulation at cell level. The three accumulation flow (3) classes identified are namely high, moderate and low accumulation flow areas.This is to enable categorizing the levels of risk (high, moderate and low) in accordance to accumulation amount. Raster Calculatorusing Boolean operators was used to query and retrieve accumulation flowareas at various levels.

Buffer Analysis for identification of elements at Risk

Buffer distances ranging from 1-500m on either side of the identified and classified flow accumulation lines was conducted to delineate landuses at risk within the defined distance. Landuses falling within the defined buffer distances of various accumulation levels are seen to be at more risk depending on the level of accumulation flow than other areas lying on very low accumulation flow areas.

RESULTS AND DISCUSSION

Results from the analysis of the various data acquired for urban flood risk delineation and analysis were presented (using maps) and discussed. The policy implications were raised and recommendations provided for sustainable urban development. The results are presented based on the following subheadings; pattern of surface flow direction and accumulation, and urban flood risk delineation.

Pattern of Surface Flow Direction and Accumulation

The result from the analysis of surface run-off flow direction (as presented in figure 5) depicts excessive flow from the central part of the metropolis towards the southern parts on one hand and from the center towards the northern parts on the other. It is evident that the direction of flow is largely influenced by the nature of the terrain which is characterized by a ridge-like feature located centrally but oriented diagonally from the North-west towards South-eastern parts of the metropolis. Excess run-off flow moves down-ward from the highlands towards the lower lands on either sides of the highland.

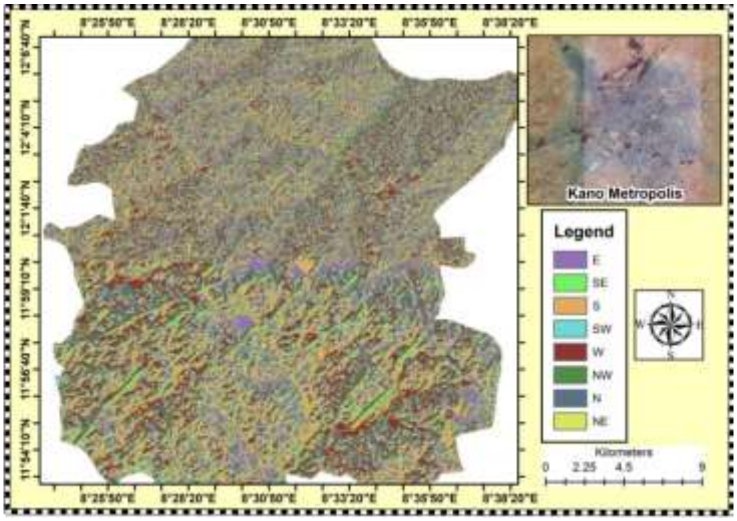


Figure 5: Surface Flow Direction Map

The major flow directions using the cardinal points are towards the S and SE on the southern axis and N, E, and NE directions on the northern axis. With the prevailing pattern of flow direction, it is easy to predict the possible areas of excess run-off accumulation and possibly flood hazard and riskscapes within the study area.

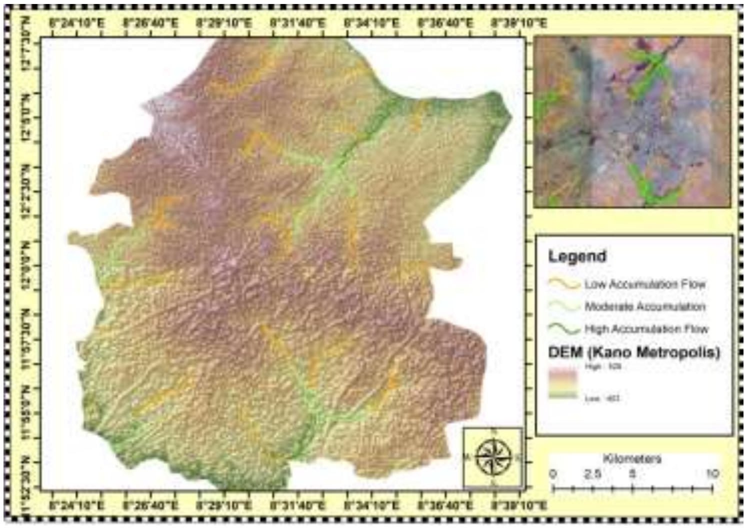


Figure 6: Surface Flow Accumulation Map

With regards to surface water flow accumulation, the result (figure 6) depicts three major flow accumulation areas based on the nature of the terrain which determines the flow direction. Depending on the amount of run-off, the amount of accumulation varies. In other words, the higher the amount of excess run-off, the more the accumulation especially at the low lands with high accumulation characteristics. And on the other hand, the more the accumulation of excess run-off, the more the flood risk within the study area. There is a direct relationship between the size of impervious surfaces within an area and the amount of excess run-off. Yunus, (2020) determined a rapid increase in the area of impervious surfaces within Kano metropolis between 2000 and 2018. Also Mohammed, Hassan and Badamasi, (2019) have extensively studied the trend and pattern of rainfall within the study area and have identified persistent increase in annual rainfall amount and intensity throughout the study period. These tremendous changes have significantly increased the amount of surface water run-off and accumulation there by increasing urban flood risk within the study area. For the purpose of this study, flow accumulation areas were identified and reclassified into three (3) major accumulation flow areas based on the expected amount of accumulation (i.e High, Moderate and Low). The reclassification was done to enable categorizing urban flood risk based on the level of excess run-off accumulation throughout the study areas. From figure 6, it is evident that the major flow accumulation areas are the lowest lands found on the either sides of the central highland. These are specifically along the floodplains of river Jakara at the Northern part and towards the lowlands along Kano- Zaria road on the southern part. On the other hand, the lower accumulation areas are located on higher lands from the center but connected (discharge their water) to the high accumulation areas.

Urban Flood Risk Delineation

This section presents the delineation of urban flood risk areas at various risk levels based on the amount of surface water accumulation. The section is categorized into three (i.e low, moderate and high urban flood risk areas).

Low Urban Flood Risk Areas

In order to delineate flood risk areas within the metropolis, the study integrated the identified flow accumulation areas at various levels (figure 6) with buffer distance of 500 metres on either sides of each accumulation area. With this, landuses at risk were identified in relation to various levels of flow accumulation. From figures 7 and 8, low accumulation areas were identified as places located on the immediate slopes from the highest peaks of the central highlands. They are characterized by steeper slopes and high velocity run-off movement towards low lands due to force of gravity. The primary activities by the moving water are more of incision and transportation of sediments and other anthropogenic wastes found on the surface rather than deposition. Low flood risk areas delineated using 500m buffer distance are areas around MAKIA, Kurna, Gwagwarwa and Kofar Ruwa (figure 7).

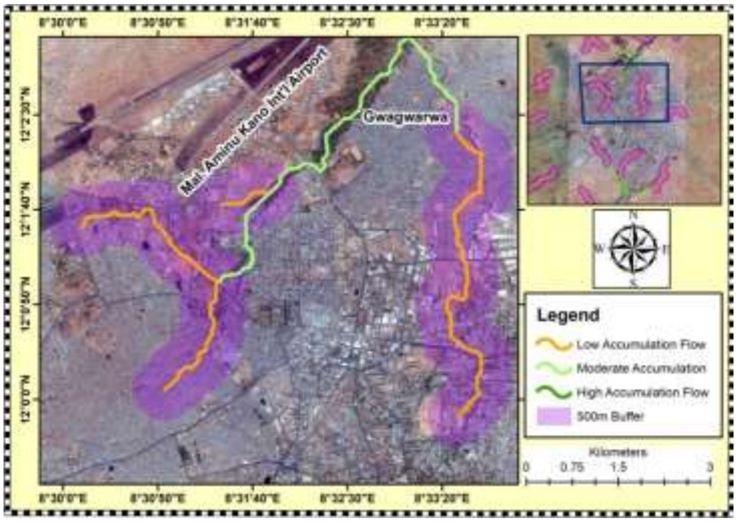


Figure 7: Low Surface Accumulation Flow Area showing part of Residential/Mixed Landuse around MAKIA at Low Flood Risk level within 500m Distance

Figure 8 shows parts of Sharada industrial and residential areas falling within the low risk areas due to low surface water accumulation.

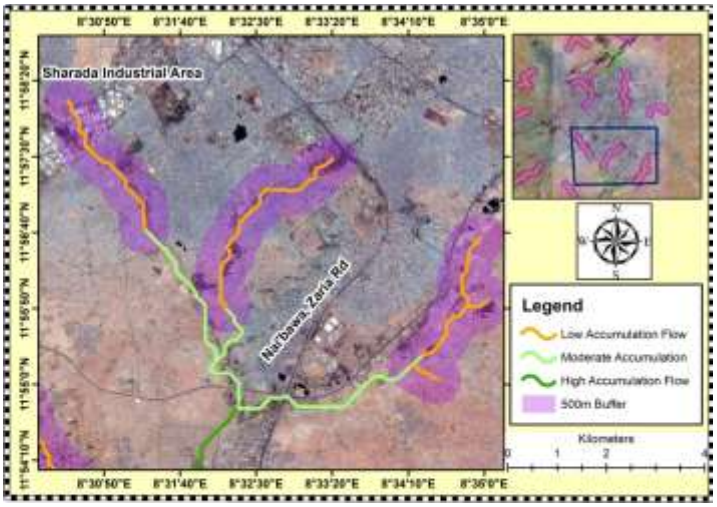


Figure 8: Low Surface Accumulation Flow Area showing part of Residential and Industrial Landuses around Sharada, and Western Bypass at Low Flood Risk level within 500m Distance

Moderate Urban Flood Risk Areas

Moderate risk areas are found within 500m distance on either side along River Jakara and part of Gwagwarwa residential area (figure 9) on the northern part of the study area. From the result of accumulation and risk analysis, it is evident that the level of risk to urban flooding increases towards areas of high accumulation and decreases towards areas of low accumulation.

Figure 9: Moderate Surface Accumulation Flow Area showing part of Residential/Mixed Landuse around MAKIA at Moderate Flood Risk level within 500m Distance

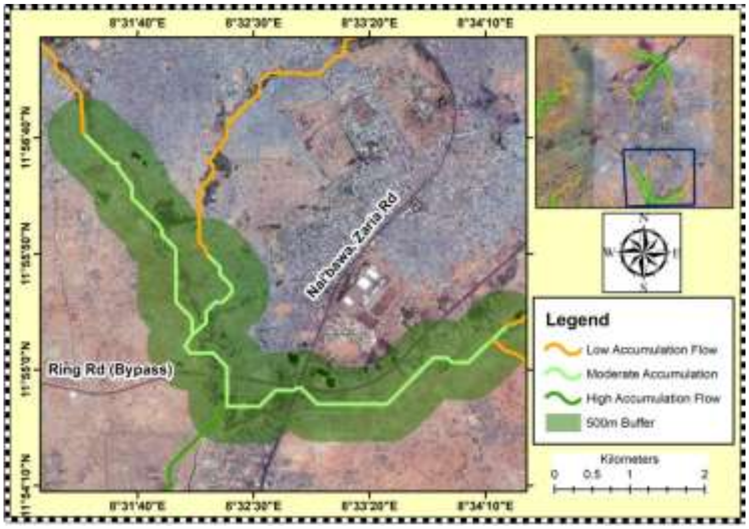


Figure 10: Moderate Surface Accumulation Flow Area showing part of Residential/Mixed Landuse around Ring Road and Western Bypasses at Moderate Flood Risk level within 500m Distance

Similarly, from figure 10, moderate risk areas delineated were found on moderate accumulation areas, thereby buttressing the fact that risk increases with increase in accumulation and decreases with decrease in accumulation. And this process is largely influenced by the pattern of the terrain and flow direction. Areas around the ring-road western bypass are also exposed to moderate risk level of flooding (figure 10) as against most of the areas within the central part of the metropolis which are located on very low or even no accumulation areas.

High Urban Flood Risk Areas

High risk areas are the most alarming areas usually found within the lowest terrain with very high amount of excess run-off accumulation. Elements including built-up and farmlands within these areas are more exposed to the threat of flooding than any other part of the metropolis. However, it is very important to note that less dense residential buildings engaging in primarily primary activities were observed to have fallen within the delineated buffer distance as presented in figure 11. Residential places specifically along the floodplains of River Jakara on the northern axis are seen to be at greater risk. Excessive flow accumulation as a result of high rainfall and continuous increase in impervious surfaces affects many buildings overtime. This results into the need for implementing and enforcing building code standards when necessary so as to reduce the risk and also mitigate the impact of flooding.

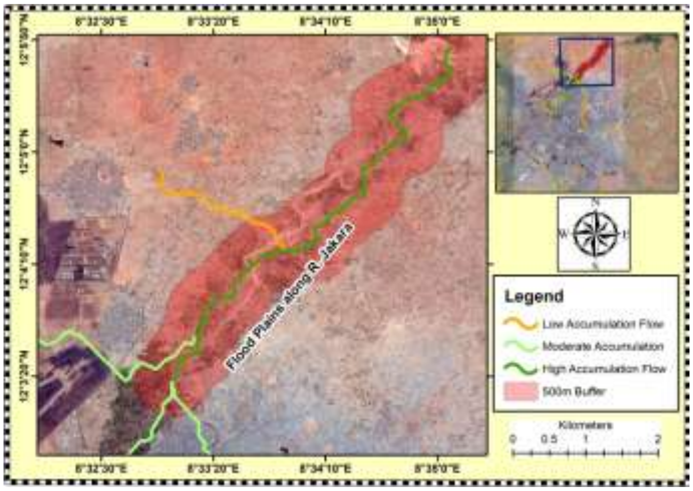


Figure 11: High Surface Accumulation Flow Area showing part of Residential Landuse along the Floodplains of River Jakara at High Flood Risk level within 500m Distance

Similarly, areas along the Kano-Zaria road covering parts of the popular Amana city and associated structures are also at high risk to urban flooding. Although the efforts towards raising structures within the Amana city, failure to do same for the surrounding will still render the city at serious risk in the future.

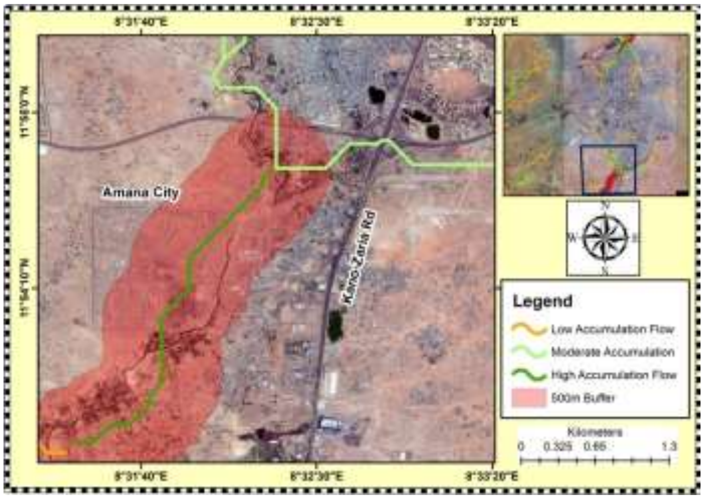


Figure 12: High Surface Accumulation Flow Area showing part of Residential Landuse along Kano-Zaria Road at High Flood Risk level within 500m Distance

It is very important to note that each of the accumulation flow area defines the duration of the expected flooding. For example, the duration of floods on the high accumulation areas (low lands) last longer and is associated to higher risk level depending on the amount of run-off than that of a flood on low accumulation area. Therefore, apart from the floodability of an area, the duration of flood is also an important factor determining the risk level and flood impact.

CONCLUSION AND RECOMMENDATIONS

In conclusion, excess surface run-off flow direction and accumulation (which are influenced by the nature of the terrain of the metropolis) are among the fundamental factors determining the risk to urban flooding. Built-up areas and farmlands exposed to high flood risk are those found on the low lands associated with high accumulation flow. Low risk areas are located on higher elevation with steeper slopes and associated to low excess run-off accumulation. The duration of flooding which defines the risk level is also dependent on the amount of accumulation which is governed by the nature of the terrain. On the basis of this conclusion, the following recommendations were made:

1. With the ongoing level of urban development and impervious surface expansion, urban planners and policy makers should make use of the excess surface water flow direction and accumulation maps in determining safer places for future developments.
2. Where structure must be erected on high risk areas, building codes should be enforced by the policy makers so as to avoid reduce risk and mitigate the impact of flooding.

3. For the existing buildings within flood risk areas, proper drainage connection and maintainace practices should be adhered to in order to reduce the impact of flooding.
4. Rainfall amount and duration should be monitored so as to be able to predict the occurrence of flooding prior to it occurrence in order to prepare for response in advance.

REFERENCES

Adelekan, O.I, (2009). Vulnerability of Urban Poor Coastal Communities to Climate Change in Lagos Island, Nigeria. *International Journal of Climatology, 18, pages 1273 – 1284.*

Agbonkhese, O., Joe-Abaya, J., Ocholi, M., & Adekunle, A. (2014). Flood Menace in Nigeria: Impacts, Remedial and Management Strategies. *Civil and Environmental Research*, *6*(4), 32-40–40. www.iiste.orgISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) Vol.6, No.4, 2014

Al Saud M., (2010). Assesment of Flood Hazard of Jeddah Area 2009,Suadia Arabia. *Journal of Water Resource and Protection , pp. 839-847, September 2010.*

Alfieri L., Thielen J., Pappenberger F, (2012). Ensemble hydro-metrological simulation for flash flood early detection”, *Elsevier Journal of Hydrology, vol. 424-425, pp.143-153, March 2012.*

Azua, S., Youngu, T. T., Aliyu, Y. A., Shebe, M. W. and Sule, J. O. (2019). Spatial Multi-Criteria Analysis for Mapping of Flood Vulnerable Areas in Fagge Local Government Area of Kano State, Nigeria. *FUTY Journal of the Environment Vol. 13 No. 1*, 23–35.

Bamidele, O. F, Badiora, A. I. (2019). Flood Disaster Vulnerability in North Central Nigeria. *International Journal of Research and Innovation in Social Science (IJRISS) |Volume III, Issue XII, December 2019|ISSN 2454-6186. III(Xii), 364–371.*

Barau, A. S. (2005). An account of the high population in Kano State, Northern Nigeria. Department of Geography, F.C.E. Kano.

Barau, A. S. (2007) The great attractions of Kano, Research and Documentation Directorate, Government house (RDD), Kano State.

Barau, A. S. Maconacchie, R. Ludinc, A. N.M. and Abdulhamid, A. (2015) Urban morphology dynamics and environmental change in Kano, Nigeria. Land Use Policy 42, 307-317.

Biondi B., and Luca D. L. D., (2013). Performance assessment of a Bayesian Forecasting System (BFS) for real time flood forcasting. *Elsevier Journel of Hydrology, vol.479, pp.51-63, 2013.*

Borga, M., Anagnostou, E.N., Blöschl, G. and Creutin, J. D., (2011). Flash flood forecasting, warning and risk management: The hydrate project. *Journal for Environmental Science Policy.**14***, 834–844.

Chan Y., and Mori M., (2011). Web-based flood monitoring system using Google Earth and 3D GIS. *IEEE International Geo science and Remote Sensing Symposium (IGARSS), pp.1902-1905, 24-29 July 2011.*

Chaochao Li, Xiaotao Cheng, Na Li, Xiaohe Du, Qian Yu and Guangyuan Kan, (2016). A Framework for Flood Risk Analysis and Benefit Assessment of Flood Control Measures in Urban Areas. *Int. J. Environ. Res. Public Health 2016, 13, 787; doi:10.3390/ijerph13080787*

Cheng, X.T.; Li, C.C., (2015). The evolutionary trend, key features and countermeasures of urban flood risk. *China Flood Drought Manag. 2015, 25, 6–9. (In Chinese).*

Daffi, R. E. Okun, J.A. and Ismail, A. (2014). Flood vulnerability assessment of River Dep floodplains in North Central Nigeria. *International Journal of Water Resources and Environmental Engineering.* ***6*** (2), 6 - 72. ISSN 2151 – 6613. Retrieved from http://www.academicjournals.org/IJWREE

Dawod G. M., and Koshak N. A., (2011). Developing GIS-Based Unit Hydrographs for Flood Management in Makkah Metropolitan Area, Saudi Arabia. *Journal of Geographic Information System,pp. 153-159, 2011.*

Dawood G. M., Mirza M. N., Al-Ghamdi K. A., (2011). GIS-Based Spatial Mapping of Flash Flood Hazard in Makkah City,Suadia Arabia. *Journal of Geograhic Information System, vol. 3, pp. 225-231, July 2011.*

Dawson, R.J., Speight, L., Hall, J.W., Djordjevic, S., Savic, D., Leandro, J. (2008). Attribution of flood risk in urban areas. *J. Hydroinf. 2008, 10, 275–288*.

Dihn, Q., Balica, S., Popescu, I. and Jonoski, A., (2012). Climate change impact on flood vulnerability, vulnerability and risk of the Long Xuyen Quadrangle in the Mekong Delta. *International Journal River Basin Management.* ***10***, 103–120.

Ejikeme, J. O. Igbokwe, J. I. Ezeomedo, I. C. Aweh, D. S. and Akinroye, R. (2015). Analysis of risks and impacts of flooding with satellite remote sensing. *Journal for Environment and Earth Science.* ***5*** (4), ISSN: 2225 - 3948. Retrieved from: www.jiste.org.

Emmanuel, A. (2016). Socio-economic impact of flooding in the Niger Delta Region. *Advances in Natural and Applied Sciences, 3(3), 369-377.*

ESRI, (2020). How Flow Accumulation works. Accessed from, https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-flow-accumulation-works.htm

Eze, N. J. Vogel, C., and Ibrahim, P.A., (2018). Assessment of Social Vulnerability of Households to Floods in Niger State. *International Letters of Social and Humanistic Sciences, 24, 22-34*

for Bandar Segamat Sustainability Using Remote Sensing and GIS Approach. *IEEE Control and System Graduate Research Colloquium (ICSGRC 2012),PP. 386-391, 16-17 July 2012.*

Hailin Z., Yi J., Xuesong Z., Baoyin H., (2010). GIS-based Risk Assessment for Regional Flood Disaster. IEEE *International*

Conference on Environmental Science and Information Application Technology, 2010.

Ikusemanran (2017) Remote Sensing and GIS for Flood Surveillance: A Case Study of Kainji Lake Basin, New Bussa, Nigeria. *Unpublished M. Tech Thesis, Department of Geography, Federal University of Technology, Minna.*

Iliyasu, U. (2017). Flood Risk Assessment in Parts of Hadejia-Jama ' are River Basin (HJRB) of Jigawa State , Nigeria. *An M . Sc . Thesis submitted to the Department of Geography, Faculty of Earth and Environmental Sciences, Bayero University , Kano*.

Itopa, M. (2019). Social Vulnerability to Flooding in Lokoja Metropolis. *Journal of Natural Disaster Reduction, 5(3), 1-23.*

Jenson, S. K., and J. O. Domingue. 1988. "Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis. *Photogrammetric Engineering and Remote Sensing 54 (11): 1593–1600.*

Jonkman, S. N. and Dawson, R.J., (2012). Issues and challenges in flood risk management. *Editorial for the Special Issue on Flood Risk Management*. ***4***, 785–792.

Khan, S. I., Hong, Y., Wang, J., Yilmaz, K. K., Gourley, J. J., Adler, and R.F., … Irwin, D., (2011). Satellite remote sensing and hydrologic modeling for flood inundation mapping in Lake Victoria basin: Implications for hydrologic prediction in ungagged basins. *IEEE Transportation Geoscience Remote Sensing*. ***49***, 85–95.

Liu J., Wen J., Yang K., Shang Z., Zhang H., (2011). GIS-Based Analysis of Flood Disaster Risk in LECZ of China and Population Exposure. *IEEE Trans. 19th International Conference on Geo informatics, Shanghai, China, June 2011.*

Maigari A. I, (2014). Evolutionary Trend, Spatial Distribution of, and Issues Associated with Markets in Kano Metropolis: *Research on Humanities and Social Sciences,* Vol.4, No.28, 2014, ISSN (Paper) 2224-5766 ISSN (Online)2225-0484 (Online), www.iiste.org

Mohammed M.U, Hassan N.I & Badamasi M.M, (2019): In search of missing links: urbanisation and climate change in Kano Metropolis, Nigeria, *International Journal of Urban Sustainable Development*, DOI: 10.1080/19463138.2019.1603154.

Nabegu, A. B. (2014). Analysis of Vulnerability to Flood Disaster in Kano State, Nigeria. *Greener Journal of Physical Sciences*, *4*(2), 22–29.

Nkwunonwo U. C, Whitworth M. and Baily B. (2015). Flooding and Flood Risk Reduction in Nigeria: Cardinal Gaps. *Journal of Geography and Natural Disasters*, *05*(01), 1–12. https://doi.org/10.4172/2167-0587.1000136

Nuissl H., and Siedentop S. (2021) Urbanisation and Land Use Change. In: Weith T., Barkmann T., Gaasch N., Rogga S., Strauß C., Zscheischler J. (eds) Sustainable Land Management in a European Context. Human-Environment Interactions, vol 8. Springer, Cham. https://doi.org/10.1007/978-3-030-50841-8_5

Nwilo, P. C. Olayinka, D. N and Adzandeh, A. E. (2012*). Global journal of Human Social Science.* ***12****, (3), 1 – 17*

Ogwuche, J. A. and Abah, I. A. (2014). Assessment of flood disaster vulnerability for flood insurance program in part of Makurdi floodplain, Benue State, Nigeria. *Donnish Journal of Ecology and Natural*

Ojigi, M. L. Abdulkadir, F. I. and Aderoju, M. O. (2013). Geospatial mapping and analysis of the 2012 flood disaster in central parts of Nigeria. *Paper presented at the 8th National GIS symposium Dammam. Saudi Arabia*.

Rozalis S., Morin E., Yair Y., Price C., (2010). Flash Flood Prediction using an uncelebrated hydrological model and radar rainfall data in a Mediterranean watershed under changing hydrological conditions. *Elsevier Journel of Hydrology,vol.394, pp.245-255, 2010*.

Samarasinghea S. M. J. S., Nandalalb H. K., Weliwitiyac D. P., Fowzed J. S. M., Hazarikad M. K., Samarakoond L., (2010). Application of Remote Sensing and GIS for flood Risk Analysis: A Case study at Kalu-Ganga River SriLanka. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, Volume XXXVIII, 2010*.

Seal V., Raha A., Maity S., Mitra S., Mukrjee A., Naskar M. K., (2012). A Real Time Multivariate robust Regression Based Flood Prediction Model using Polynomial Approximation for wireless sensor network based flood forcasting system. *Springer Journal of Advances in Computer science and information Technology, vol.86, pp. 432-441,v2012.*

Simonovic, S.P., (2011). Systems approach to management of disasters: methods and applications. New York: John Wiley & Sons.

Sulaiman N. A., Husain F., Hashim K. A., Samad A., (2012). A Study on Flood Risk Assessmentfor Bandar Segamat Sustainability Using Remote Sensing and GIS Approach. *IEEE Control and System Graduate Research Colloquium (ICSGRC 2012),PP. 386-391, 16-17 July 2012.*

Xiaomeng Y. M., Xiaojuan L., Sun L. Y., Li X., (2011). Rapid Assessment of Flood Disaster Loss in Sind and Punjab Province, Pakistan Based on RS and GIS. *IEEE Trans. (ICMT) International Conference on Multimedia Technology, PP.646-649, Beijing, China, July 2011.*

Yunus S. and Khalid A. M., (2020). Urban Flood Hazardscape Pattern and Vulnerability Dynamics in Kano Metropolis, Kano State, Nigeria. Submitted to Confluence Journal of Environmental Studies for publication.

Zhang J., Song L., Feng F., Gong H., (2010). Hydrologic Information Extraction for Flood Disaster Risk Assessment in Pearl River Basin and Luan River Basin, China. *IEEE Trans. International Conference on geoinformatics,pp.1-4, June 2010.*