

STORMWATER EVALUATION AND MANAGEMENT IN THE URBAN WATERSHED OF UYO METROPOLIS, NIGERIA, EMPLOYING GIS SIMULATION

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ABSTRACT	KEYWORDS
<p>In several Nigerian cities, storm water management is a significant challenge. Local flooding is common in urban settings because storm water is channeled along streets because runoff may not be able to escape the environment and create floods. As a result, severe rains are related with floods and other disasters in Nigerian cities. Storm water harvesting from point sources, water management, and purification (treatment) are sustainable techniques that can make metropolitan environments self-sufficient in terms of water supplies. The study aims to evaluate stormwater generation and management, which encompasses hard and soft engineering projects involving the construction, operation, and maintenance of dams, artificial levees, and other structures that are comparable like dams, artificial levees, and channel straightening are examples of construction, operation, and maintenance approaches. To achieve the study's goal, the researchers used a correlational research design in which data was analyzed using hydrological modeling techniques and</p>	<p>GIS, Stormwater, Modelling, Urban, Catchment.</p>

GIS. As a result, a model was created to depict stormwater generation by balancing and overlaying DEM data in a pairwise comparison of stormwater flow against rainfall intensity and topography pattern using multi criteria evaluation. The investigation and findings demonstrate that the simulated sub catchment runoff in Uyo metropolis is higher than expected, whereby four catchments were used for the runoff generation, it is vividly shown that the total precipitation in each of the sub catchments is similar which was 1.57 inches while the total infiltration read 0.79 inches, the total runoff was 0.74 inches and 0.08x 106 gallon. The study concludes that better city planning is required to manage the stormwater problem through various engineering projects, based on the findings. The following are some suggestions: To achieve sustainable urban growth and development, implement the uyo City Master Plan to guide, monitor, control, and manage the areas designated as urban lands. Storm Water Management Framework should be prepared for the city having Storm Water Master Plan to control, manage, and monitor storm water as a state policy and urgency – Model for Urban Stormwater Improvement Conceptualisation (MUSIC), 2002 Approach, Structural (engineering methods) and Non-structural (regulations and standards) Storm Water Management approaches should be employed to control and manage flooding challenges in the city.

INTRODUCTION

For the past three decades, the rate of loss and destruction caused by disasters, whether human or natural, has been frightening, resulting in significant economic loss and the deaths of millions of people. Natural and human-induced disasters are rapidly becoming the main point for terrible destruction and losses in urban areas, where roughly half of the world's population now lives and most of the world's human-made constructions are located (UN-HABITAT, 2007). Rapid urbanization, in combination with global environmental changes as a result of climate change and intense human activity, has resulted in an increase in susceptible or exposed locations (disaster hotspots) that are currently acting as human settlements (UN-HABITAT, 2007).

Flood disaster is described by UN-HABITAT (2007) as a circumstance in which people's resistance is overwhelmed by the volume of stormwater/runoff created in a location due to excessive rainfall intensity. Landslides, mudslides, flooding, droughts, earthquakes, tsunamis, volcanoes, avalanches, ecological destruction, and fire are examples of natural or human-caused disasters. The assessment of storm water management and challenges that cause pluvial flooding and environmental degradation in settlements, particularly in urban areas, as well as the plan for effective storm water management in Uyo metropolis, are the focus of this research.

In numerous Nigerian cities, storm water management is a big concern. Local flooding is common in urban settings because storm water is channeled along streets because runoff may not be able to escape the environment and create floods (Bryan 2002). As a result, severe rains are related with floods and other disasters in Nigerian cities. This human-caused disaster is a serious problem and source of concern for global populations, particularly in urban regions where the ground has been heavily paved

and concretized as a result of urban expansion. This has resulted in significant environmental, social, health, and economic concerns in the built environment, both in industrialized and developing cultures (Enger, et al, 2006), with the latter being more common. Many developed cities used to have a single system to handle both sewage and storm water runoff, which meant that during heavy rains, the runoff from streets could be too large for waste water treatment plants to handle, and the waters would be directed to any nearby natural water bodies without being treated. For easy treatment and handling, sophisticated communities have segregated sewage and storm water runoff (Enger, et al, 2006).

Storm water, according to the Encarta Dictionary (2009), is water that has been channeled into a man-made or natural drain large enough to contain surplus water that has overflowed the surface. Storm water is described as water that runs off of streets and buildings and is frequently pumped into the sewage system and transferred to a municipal wastewater treatment facility (Enger, et al, 2006). In the environment storm water can infiltrate into the soil, also held on the surface of the earth and evaporate, or overflow and emptied in nearby streams, rivers, or water bodies in the environment . The soil absorbs much of the storm water in natural landscapes like forests and grasslands, and plants hold storm water close to where it discharges.

Unmanaged storm water can pose two primary issues in built-up areas: one relating to the volume and timing of runoff water (flooding), and the other related to potential contamination from contaminants carried by the runoff (water pollution) (Schueler, 2000); Alex and Robert (2005). Storm water is an important resource because, as a result of rapid population increase, the world's human population's water demand surpasses readily available water for consumption. This is especially true in urban areas, where the majority of the world's population is concentrated. Storm water harvesting from point sources, water management, and purification (treatment) are sustainable techniques that can make metropolitan environments self-sufficient in terms of water supplies. Because storm water can contain fertilizers, oil, pesticides, trash, sediment, and animal wastes from human activities, it is one of the leading contributors to pollution of urban waterways. As a result of this situation, certain storm water discharges in developed countries are regulated by Environmental Protection Agencies (EPAs) (AHTD, 2015). In recent decades, there has been a significant increase in the occurrence and intensity of extreme rainfall events, as well as an increase in the frequency and intensity of floods (Temi and Durowoju, 2014). As a result of increased human development activities, runoff increases, resulting in poor surface and ground water quality, raising concerns about the treatment and monitoring of storm water, as well as ensuring better surface and ground water quality as a result of storm water through engineering solutions (Bryan, 2000).

Coastal settings, like Nigeria, are characterized by environmental dangers linked to water-related problems coming from inefficient storm water management. Storm water management is a challenge in the Niger Delta region, which is a coastal region and a floodplain, especially in the cities, which are a converging point for population. However, in addition to this geo-hazard, the rise in population and human heedless interference with the environment in pursuit of industrialization, agriculture, urbanization, and settlement growth, among other things, have resulted in major ecological and socio-economic difficulties (Oyeleke, 2014). As a result, the goal of this research is to look at how stormwater/runoff is generated and managed throughout catchments in the Uyo urban drainage basin.

STUDY AREA

The Uyo Metropolis is located between latitudes 4°32'N and 5°33'N of the equator, and longitudes 7°25'E and 8°25'N of the Greenwich Meriden (Census, 2006). The state capital of Akwa Ibom is Uyo. The population of Uyo metropolis is 427,873 (NPC), with an estimated population of 7124440. (2019 Population Estimate). It covers 362km² and has a density of 1,200km² (1,300 per square meter). Uyo metropolitan has a unique characteristic climate, with an average annual rainfall of 250gmm and a temperature of 26.4oC. (Oyegun, 1994). The study area's relief and drainage are such that it falls within the coastal belt, which is dominated by low-lying coastal plains that are structurally related to the Agbada and Akata formations. Because the area is low lying coastal, the flow of water and surface runoff has kinks in the flow pattern. Coastal lowlands are crisscrossed by a labyrinth of swamp, creeks, and waterways, indicating a paucity of firm and vast land mass. The area's soil and geology are made up of a variety of super fine deposits that lie on top of thick tertiary sandy and clayey deposits that can be over 100 meters thick in places. The area's persistent high rainfall and warmth promote severe chemical weathering of the rocks, resulting in the development of clay minerals that are found across the region (Oyegun, 1994). The soils in the area are divided into two categories: those produced from sediments and those formed on younger quaternary and recent alluvium.

LITERATURE REVIEW/CONCEPTUAL FRAMEWORK

STORM WATER GENERATION AND MANAGEMENT

Rivers, in general, are a major contributor to the storm water problem, which results in flooding. When they induce floods, the consequences are disastrous, destroying livelihoods, causing economic loss, and even killing people. This is why people try to find ways to deal with them, whether it's to prevent floods in the first place or to mitigate the effects. Rivers, on the other hand, are unpredictable natural creations with a high degree of volatility. It is impossible for man to completely prevent them from causing flooding, but he can control them to reduce the impact on humans and the environment. However, there are two main storm water management systems that span both hard and soft engineering projects that can be used to manage storm water without causing flooding.

Rather than preventing flooding, the soft engineering initiatives focus on decreasing and alleviating the effects of storm water problems that result in flooding incidents. Soft engineering's main advantage is cost efficiency and efficacy, as it is less expensive to implement and can be done by developing countries as well. The construction, operation, and upkeep of buildings has a low impact on education and technology implementation. In general, unlike their hard engineering project counterparts, they do not disrupt natural processes and ecological systems in river basins, but rather integrate with the natural system to achieve environmental sustainability (Alex, n. y., 2016).

HARD ENGINEERING TECHNIQUES

Dams are extreme and hard engineering practices that have an impact on the environment, particularly along rivers and floodplains. The beautiful engineering structures act as reservoirs for water and slowly drain water in a controlled manner to avoid flooding. Even during months of heavy rain, this helps keep discharge downstream of the dam low. It not only prevents flooding, but it also supplies hydroelectric power to a number of villages, promoting socioeconomic growth and development. The dam's reservoir can be used for water supply as well as recreational purposes.

Despite their numerous advantages, dams pose a number of environmental risks. Dams are costly and technologically demanding of all hard engineering approaches in the world, as they take a large amount of resources to create. The villages behind a dam frequently experience severe flooding, which can devastate habitats and properties, forcing residents to flee their homes (Alex, n.y., 2016). Dams obstruct natural processes that occur within river ecological systems by preventing sediments from being carried downstream, which can result in the destruction of delta landforms and habitats. In addition, the chemical makeup of the water is altered, reducing the chances of aquatic life surviving.

ARTIFICIAL LEVEES

Artificial levees are artificial versions of the river edges. They act as embankments just like their natural counterparts, and basically extend the channels height and increase their bank-full discharge. The primary benefit of an artificial levee is that it allows the floodplain to be developed upon which also have environmental consequences as it increases the risk of flooding from precipitation and river surge to the people that occupies the area and create ecological imbalances in the environment (Alex, n.y., 2016). However, if they fail, the consequences are overwhelming and even worse than if the levees did not exist at all.

CHANNEL STRAIGHTENING

This method of flood control is shutting off meanders by building alternate and straighter pathways over meanders, allowing the river to flow more quickly and easily. This technique, like wing dykes, channels river water in a faster mode, preventing it from pooling at a point and posing a flood risk. Straightening the channel makes it easier to navigate the water and straightening the canal. This method has various drawbacks. For example, due to river dynamics, the downstream of a straightened stretch of a channel frequently experiences flooding and erosion (Alex, n.y., 2016).

Effects of Climatic and Hydrological Factors On Storm Water Management

The magnitude and frequency of large rainfall events present significant challenges for stormwater management which most times the transporting system such as drainage are overwhelmed and filled beyond capacity and overflow and most coastal areas are exposed to risk of flooding (Liebl, 2011). For example, the U.S. Geological Survey (USGS) has created a synergy with the City of Charlotte and Mecklenburg County in North Carolina, and develop Flood Information and Notification System (FINS) used to check and address rapid flooding in the area by notifying future flooding occurrence in these urban areas where streams rise and fall rapidly (U.S. Geological Survey, 2003).

The FINS is based on a large network of stream flow-gaging and rainfall stations that will broadcast information recorded through radio telemetry. This system routinely notifies the National Weather Service (NWS) and emergency agencies to respond rapidly in the region when rainfall and stream flow which indicate the eminent risk of flooding occurrence, for the agencies to issue warning signals to the people for evacuation and preparedness in the areas if necessary (Konrad, 2014; Carter, 1961).

Water bodies such as streams, rivers, lakes, etc. are naturally fed by runoff from rainfall and snowmelt moving overland or subsurface flow. Flood incidence may occur when large volumes of runoff flow rapidly into water bodies and overwhelm the banks of these water bodies causing inundations and rivers surge. The rapid discharge of water that causes flooding is influenced by many factors including the intensity and duration of rainfall and snowmelt, the topography and geology of natural water basins,

level of vegetation in the environment, and the hydrologic conditions prior storm and snowmelt events (Konrad, 2014).

Modest storage capacity for water from rainfall and snowmelt in urban basins, generate more rapid runoff and urban water bodies rises more rapidly during storms and have higher peak discharge rates than do rural streams. For example, streamflow in Mercer Creek, an urban stream in western Washington, increases more quickly, because of higher peak discharge and volume during the storm in 2000, and decreases more quickly than in Newaukum Creek, a nearby rural stream in the same region. These differences cannot be attributed to landuse patterns in the various creeks but reflect differences in geology, topography, basin size and shape, and storm patterns (Konrad and Booth, 2002).

Hydrology affects urban development and most times significant in small stream basins where before urban development, much of rainfall on the basin would have become subsurface flow, recharging aquifers or discharging to the stream network. Urban development can totally change or alter the landscape in a small stream basin, unlike in larger river basins where areas with natural vegetation and soil are likely to be retained because of the extent of land and water basin (Konrad, 2014; Leopold, 1968).

Developing along stream channels in floodplains may distort the capacity of water channel to transport water which may increase the height of the runoff. Buildings and other developments that encroaches on floodplain, such as bridges, can increase upstream flooding by narrowing the width of the channel and increasing the channel's resistance to flow. Since, the water is at a higher stage as it flows past the obstruction, it can cause backwater which may give rise that to inundation of upstream because of sediments and debris carried by the flood (Konrad, 2014; Bailey, et al, 1989). Small stream channels also can be filled with sediment and cause clogging because of the size of the culvert in the stream. However, such channels can be engineered through the conveying of floodwater and debris quickly downstream, which may benefit the area and balanced against the possibility of flooding in downstream (Konrad, 2014).

Erosion is another consequence of urban streams as it effects urban development. The frequent development in urban water bodies increases flooding and causes bank erosion along the water channel path. Where river channels have been altered and vegetation has been removed from channel banks, streamflow velocities will increase and enhance the transportation of sediment along the river rapidly. In many urban areas, stream bank erosion continue to be threat to roads, bridges, and other structures which is difficult to control even by hardening stream banks (Konrad, 2014). In view of the above, stormwater generation is prevalent in the urban catchment. This has caused severe environmental hazards in the urban catchment and calls for adequate management to prevent future occurrences. It is against this background that this research was undertaken on "stormwater evaluation and management in the urban watershed of Uyo Metropolis, Nigeria, employing GIS simulation".

MATERIALS AND METHODS

This study adopted the correlational research design. The correlational design approach is being used in this study to measure the strength of the relationship between runoff (stormwater) and the associated risk of vulnerability on flood prone areas in the study area. Hence, data for the study was the secondary data acquired from Landsat imageries of the study area showing the digital elevation of the area and the water shed pattern. The data for this study was analyzed using hydrological models and modeling

techniques to achieve the objective of the study. The volume of Water generated was plotted against the intensity of rainfall to get the stormwater generation as showed in the hydrograph.

Thus a model to show the storm water generated was done by Weighing and overlaying the DEM data in the principle of pair-wise comparison of storm water runoff against rainfall intensity and terrain pattern using multi criteria evaluation techniques. Thus, the enhanced Digital Elevation Model (DEM) developed for the small catchment across cities was used. This technique was adopted by Amro et al (2019) in assessing flash flood risk in urban environment of Taibah and Islamic University Campuses of Kingdom and Lian et al, (2017) on flash flood vulnerability assessment for small catchment with material flow approach to show the relationship between exposure, sensitivity and adaptive capacity in a small catchment and it is replicated in this study. Adopting the procedure of Amro et al (2019) and Lian et al, (2017), a flood hydrograph for the small catchment across the city of Port Harcourt was generated using enhanced DEM and acquired to model the approach of runoff/storm water generated.

RESULTS AND DISCUSSION

Occurrence/Variation of Stormwater Generation Across the Cities in the Study Area

Table 1: Stream Parameters

Stream Parameters	Uyo metropolis
Total Stream Length (m)	339991.67
Average Stream Length (m)	1086.24
Number of Streams	313
Standard Deviation	886.39
Minimum (m)	46.08
Maximum (m)	5771.86
Highest Flow Length (m)	0.17

STORM-WATER GENERATION IN UYO METROPOLIS

The descriptions of stream parameters in uyo Metropolis is shown in Table 1 above in Uyo metropolis, the analysis showed that the total length of streams was 339991.67m and the mean length was discovered to be 1086.24m. In total, there were 313 streams in Uyo Metropolis and the highest flow length was 0.17m. There were 251 streams that were found in Uyo Metropolis and the highest flow length was 0.14m. From the analysis, it can be deduced that there are more streams in Uyo the average length of streams was higher in Uyo metropolis.

The sub-catchment analysis in the study areas revealed that uyo metropolis had more basins 654 sub basins. The total area of basins in metropolis was 446101922.54 sqm . In Uyo metropolis, the area ranged between 5456.12 sq.m to 68591447.12 sqm. with the mean value of 1388006.17 sq.m.

Table 2: Sub Basin Parameters

Sub Basin Parameters	Uyo metropolis
Total Number of Basins	654
Total Area (Sq. m)	446101922.54
Minimum (Sq. m)	5456.12
Maximum (Sq. m)	68591447.12
Average Area (Sq. m)	1388006.17
Standard Deviation (Sq. m)	4246555.79

Source: Researchers' Analysis, 2020

The Digital Elevation Model of Uyo metropolis was found to range between -6m to 39 m (Figure 1) and there are quite sub-basins of varying sizes in Uyo metropolis (Figure 3). The flow length of streams in Uyo Metropolis ranged from 0 m to .174054m (Figure 4). This shows that the topography of Uyo metropolis is higher. The flow length of streams in sub- basins ranged from 0m to 0.144281 (Figure 7).

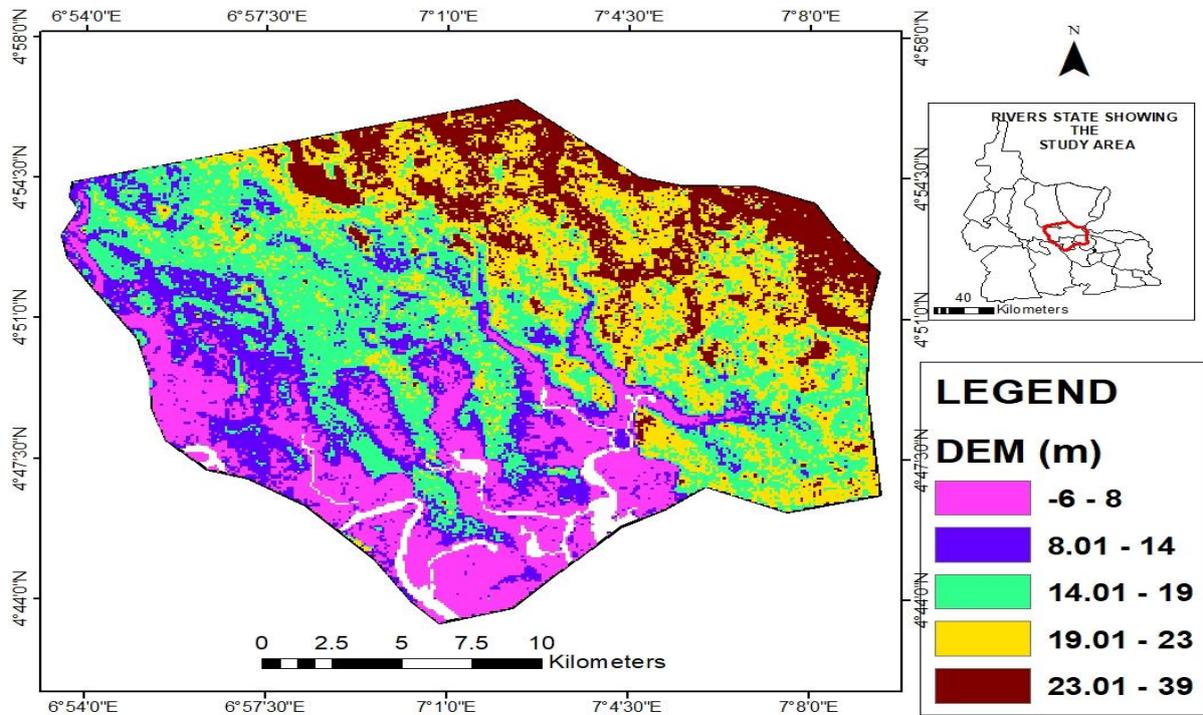


Figure 1: DEM of Uyo Metropolis

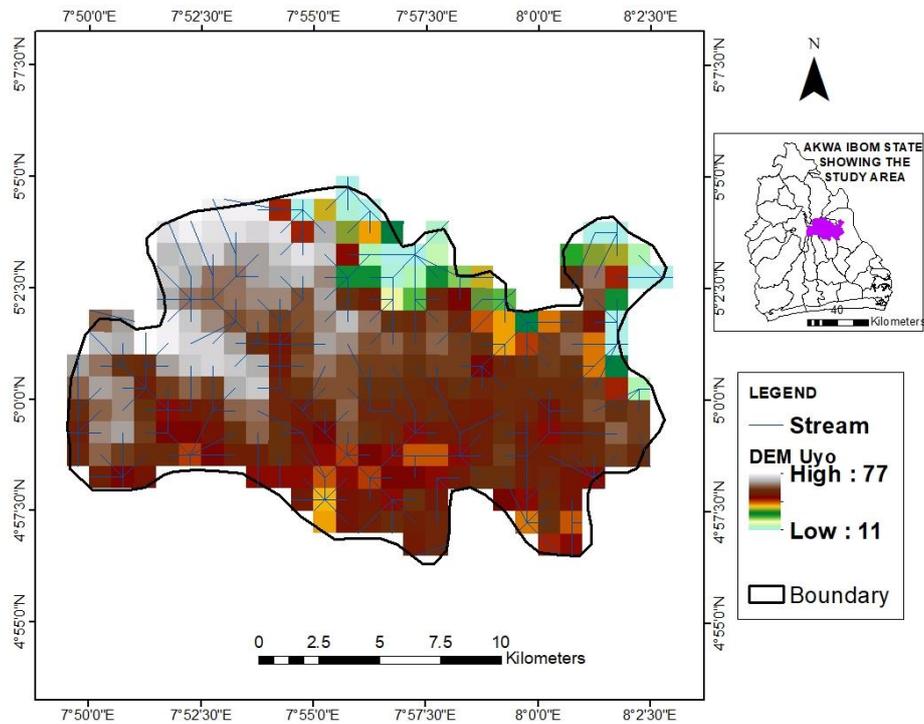


Fig. 1: DEM of Uyo and Streams

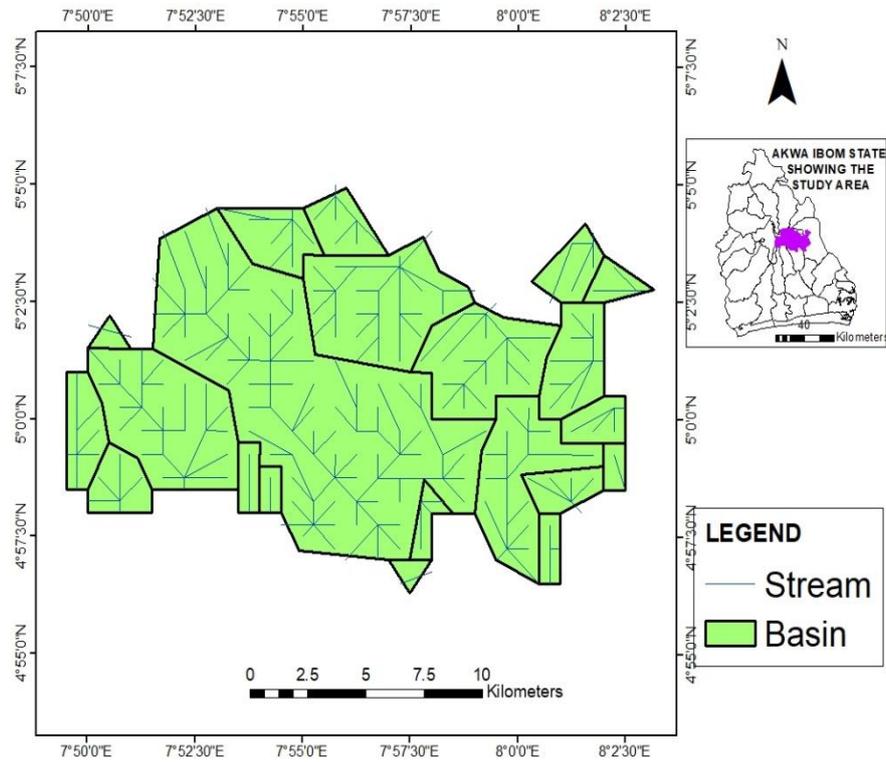


Fig. 2: Streams and Basins

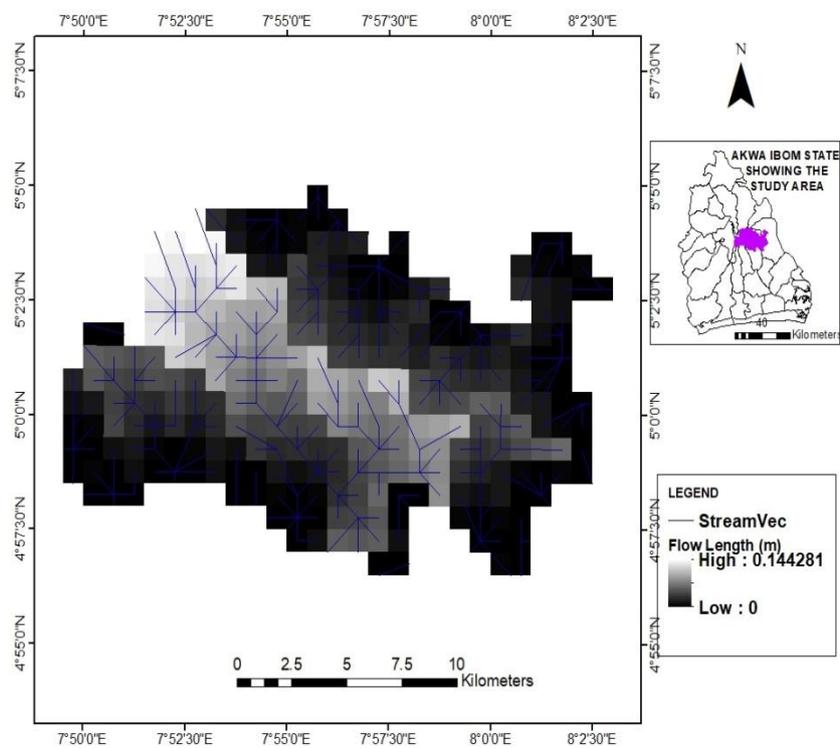


Fig. 3: Flow length of Flood in Uyo Metropolis

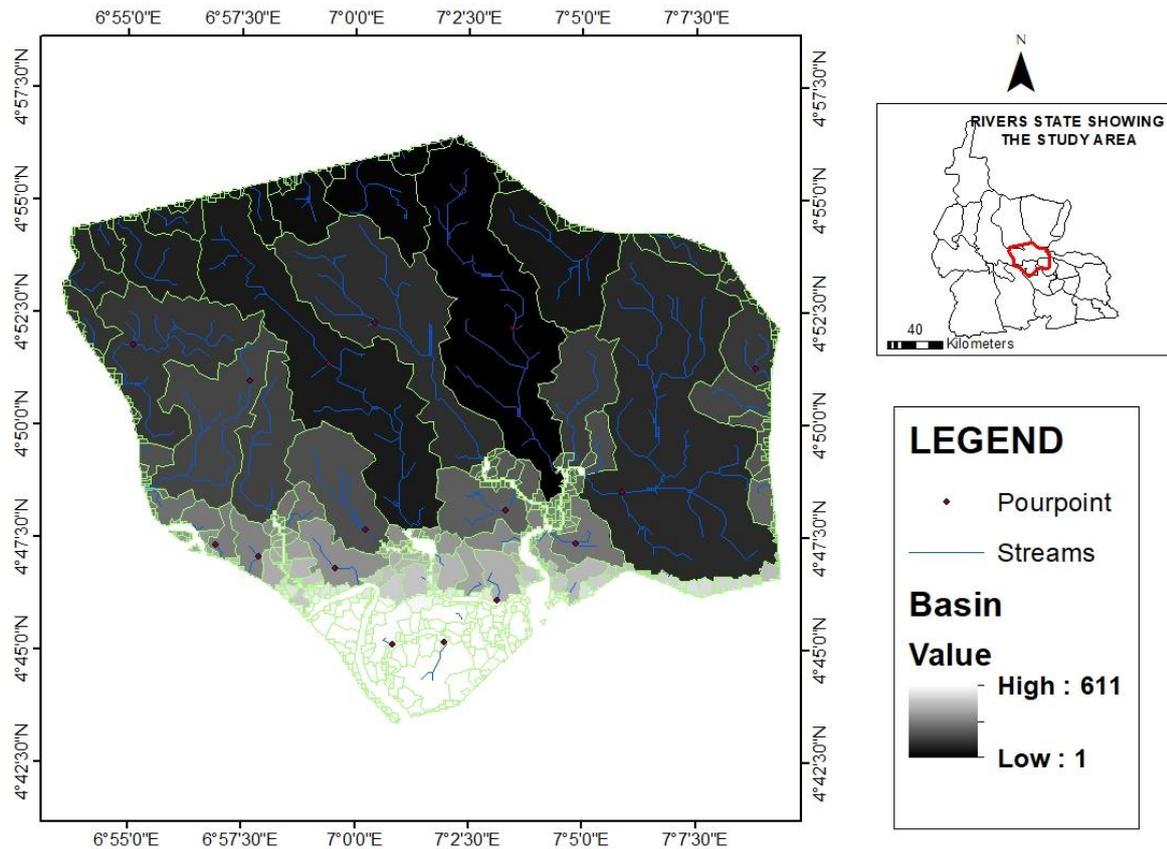


Figure 4: Basins and Streams in Uyo Metropolis

STORM WATER ATTRIBUTES IN THE STUDY AREA

Table 5 summarised the simulated sub-catchment runoff in Uyo metropolis whereby 4 sub catchments were used for the runoff generation. It is vividly shown that the total precipitation in each of the sub catchment is similar which 1.57 inches was while the total infiltration read 0.79 inches. The total runoff was 0.74 inches and 0.08×10^6 gallons.

The link flow analysis through the conduit or pipe reveals that the range of maximum flow of the conduit was from 0.73 CFS to 3.64 CFS while hours of flow were 6 hours. It is thus observed that the conduit C36, C38 and C39 having similar maximum flow still exhibited different rates of maximum velocity. Thus, C36 had 3.56 ft/sec, C38 had 4.22 ft/sec while C39 had 3.92 ft/sec. The other two conduits namely C37 and C40 with higher flow maintained higher velocity as they had 5.26 ft/sec and 9.35 ft/sec respectively. It is equally discovered that the maximum full flow was higher in the conduits with higher flow velocity. The maximum full depth of the conduit appeared to range from 0.11 ft (C38) to 0.26 (C40). Generally, it is shown that flow; velocity of flow, full flow and full depth of conduit followed almost the same pattern against each of the conduit.

The nodes or junctions of inflow in Uyo Metropolis were seen to have equal maximum of lateral inflow of 0.73 CFS. It is however discovered further that the maximum total inflow ranged from 0.73 CFS in J36, J38 and J39 to 3.64 CFS in J40. The Outfall was also having 3.64 CFS total inflow. Although the lateral inflow volume in all the nodes was similar (0.0796×10^6 gal) but the total inflow volume of the nodes varied and ranged from 0.0796×10^6 gal to 0.396×10^6 gal; whereas the outfall had 0.394×10^6 gal. It could be deduced from the analysis that total inflow is proportional to the total inflow volume in the nodes or junctions.

The node depths in Uyo Metropolis are given in Table 4.6 had varying depths ranging from 0.12 ft in J38 to 0.27 ft in J40 and Out1. The maximum depth among the nodes was highest in J40 and Out 1 (0.39 ft) while the minimum was found in J38 (0.17 ft). The maximum HGL ranged from 13.39 ft in J40 to 23.2 ft in J36. The maximum HGL in Out 1 was 3.39 ft.

The outfall loading revealed that the flow frequency was 82.36% while the average flow was 2.97. The maximum flow was 3.64 CFS and total volume of storm water was 0.394×10^6 gal in Uyo Metropolis.

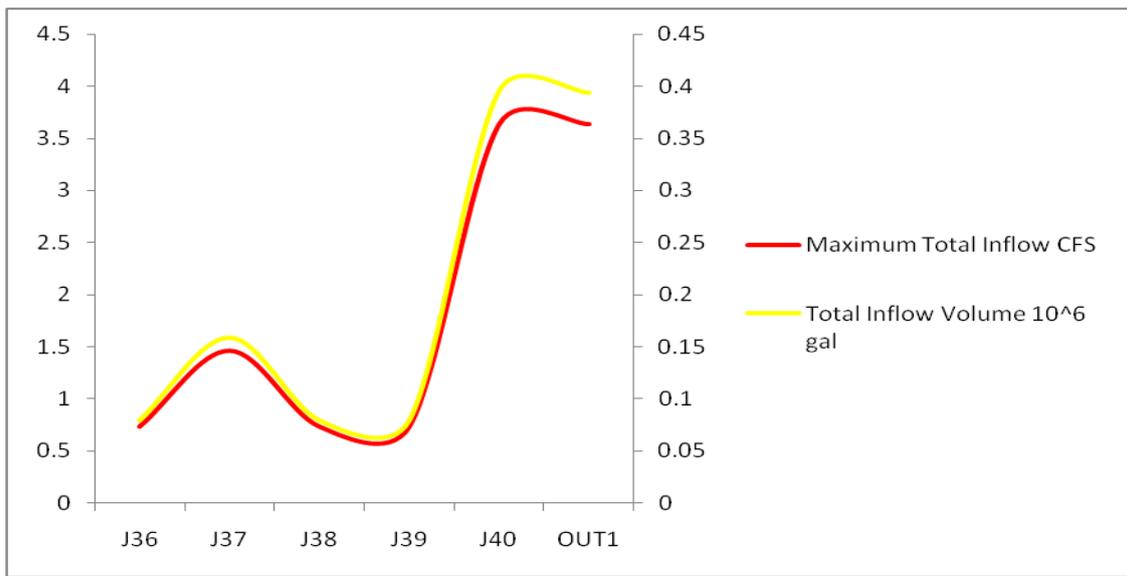


Figure 5: Maximum Total Inflow and Total Inflow Volume in the Nodes in uyo Metropolis

SUB CATCHMENT RUNOFF, NODE FLOODING, AND LINKING VOLUME

The sub catchment runoff, node flooding and linking volume of Uyo metropolis is observed here. The situations at different times of the day are shown in Figures 4.20 (0.00-01.00mins), 4.21 (01.15-01.30mins), 4.22 (01.30mins-01.45mins), 4.23 (01.45mins-05.15mins), and 4.24 (05.15mins-06.00mins) in uyo Metropolis. The analysis revealed that the catchment runoff, node flooding and linking volume increased with increasing time of the day. The sub catchment runoff ranged from 0 in to 0.73 in; node flooding ranged from 25 to 100 CFS while link volume ranged from to 100 ft³ to 460 ft³. The simulation of the sub catchment runoff, node flooding and linking volume was not deduced.

Nature of Water Elevated Profiles/Hydrographs in The Study Area

The nature of water elevated profiles or hydrographs though the conduit between different nodes and the outfall in the study area are discussed in this section. For Uyo Metropolis, the water elevation profile included from Node 36 to Out 1; and that of Node 38 to Out 1.

DISCUSSION OF FINDINGS

The study compared the storm water generation and flood vulnerability between Uyo metropolis. Due to devastating effect in Urban areas resulting to destruction of Property and displacement of millions of people, sporadic urbanization, human attraction, Landuse/landcover changes. uncontrolled development, encroachment of floodplains which occurs as a result of flash flood, blockage of river

channels, drainages. shoreline inundation, devastating human impact on the hydrological cycle, The Findings of the study showed that Uyo metropolis the total stream length, number of streams and the flow length was higher in Uyo metropolis.

The sub catchment runoff, Node flooding and link velocity of both Uyo metropolis as presented in Table 4.16, figure 4.25 (0.00 mins – 01/15mins), figure 4.26 (1.15mins – 1.30 mins) and (1.30mins – 6.00mins) present the sub catchment runoff, Node flooding and link velocity a Uyo metropolis. Similar to other analysis and findings, the runoff, and flooding increased with increasing time of the day while the velocity increased from 0.01ft/sec to 2ft/sec at 1.30mins, and begin to reduce and stayed at 1ft/sec. The analysis/findings in figure 4.28/0.00mins – 03.30mins, 4.29 (03.30mins – 0.400mins) and 4.30 (04.00mins) – 06.00mins indicated three different major changes during the simulations in any of the combined parameters (runoff, flooding or velocity).

Table 4.17 revealed according to finding that the sub catchment run off and node flooding remained unchanged throughout the hour considered. While the link velocity fluctuated from 10.01ft/sec to 0.78ft/sec at 3.30mins and later increased at 4.00mins for the remaining hour of the day. The nature of water selected profiles/flood hydrograph of the study areas. In Uyo metropolis were the water elevation profile included from node 36 to out 1 and that of node 38 to out 1. The one from node 36 to out 1 has increasing in elevation with increasing distance to the outfall while the one for node 38 to out 1 outlined to decrease. Analysis and findings for flood vulnerability in Uyo metropolis revealed that the landuse map vulnerability to flood according to each landuse identified in the study area. The study revealed the types of landuse discovered and the spatial extent of each of them. The analysis further showed that the spatial extent of the area for moderate flood vulnerability was 48.7% while high flood vulnerability was 51.3%.

Accordingly, the analysis further explained the types of landuse discovered and the spatial extent of each of them, built-up area (141783308.91m²) vegetation patches (50813320.29m²). The findings revealed farmland /space vegetation recorded 35785889.00m² while water bodies and vegetation patches 10.37% and 19.94% respectively. The findings also showed that spatial extent for moderate flood vulnerability was 33.98% while high flood vulnerability was 66.02%.

SUMMARY

The study compared the storm water generation and flood vulnerability between Uyo Metropolis. Findings showed that Uyo the total stream length, number of streams and the flow length was higher in Uyo. However, the average stream length was higher in Uyo Metropolis. Considering the number of sub basins in the study area, findings showed that Uyo had more (654) sub basins. although the average area of the basin was higher in Uyo. The digital elevation in Uyo metropolis was lower in range. For Uyo metropolis, it ranged between -6m to 39m. The total runoff in Uyo Metropolis was higher in Uyo Metropolis (0.74) inches, the maximum flow was 3.64 CFS and total volume of storm water was 0.394×10^6 gal. The analysis revealed that rate of change of catchment behaviour. The catchment precipitation, node flooding and runoff in both study areas continued to increase with increasing time of the day, although the rate of change of the volume of runoff varied slightly between Uyo metropolis. The width of the hydrograph in Uyo metropolis was wider. The areas prone to moderate and high flood in Uyo metropolis was higher (95.03%).

CONCLUSION

The study can be concluded that the runoff generated in Uyo metropolis was higher. Also the flood vulnerability level of Uyo metropolis is higher considering the landuse, elevation, proximity to river and soil texture.

RECOMMENDATIONS

Based on the findings, the study suggested the following recommendations.

1. Government should be fully prepared against flood intensity because of the level of vulnerability to flood in Uyo metropolis as revealed by the study.
2. The area liable to moderate and high flood vulnerability should be well guided and guarded to minimize the destruction of lives and properties.
3. Better planning of the cities is required to regulate the effect of flooding in the study area.
4. The implementation of the Uyo city Master Plan to guide, monitor, control and manage the areas designated as urban lands to achieve sustainable urban growth and development; [2] as a state policy and urgency, Storm Water Management Framework should be prepared for the city having Storm Water Master Plan to control, manage and monitor storm water – Model for Urban Stormwater Improvement Conceptualisation (MUSIC), 2002 Approach, Structural (engineering methods) and Non-structural (regulations and standards) Storm Water Management approaches should be employed to control and manage flooding challenges in the city;
5. Proper planning and layout of residential, commercial and industrial areas for easy construction of drainages and channelling of storm waters to natural drainage systems in the city; [5] HEC-1 and HEC-RAS softwares should be used to analyse and estimate natural drainage systems hydrology, hydraulic and flow systems of channels;
6. Detailed topographical and geological surveys and analysis of the study area should be carried out before storm water infrastructure be provided for proper flowing and channelling of storm water;

REFERENCES

1. Alex, J. (n.y). Flood Management. Published: Geography AS Notes, Retrieved 28th March, 2016, from <https://geographyas.info/rivers/flood-management/>.
2. Alex, M. & Robert, P. (2005). "The National Stormwater Quality Database, Version 1.1: A Compilation and Analysis of NPDES Stormwater Monitoring Information". Washington DC, Center for Watershed Protection, Report prepared for U.S. Environmental Protection Agency. September 4, 2005.
3. AHTD (2015). Welcome to the Arkansas State Highway and Transportation Department Storm Water Program. Published: Arkansas State Highway and Transportation Department. Retrieved 6th March, 2016, from <http://www.arkansashighways.com/stormwater/stormwater.aspx>.
4. Bailey, J.F., Thomas, W.O., Wetzel, K.L. & Ross, T.J. (1989). Estimation of Flood-Frequency Characteristics and the Effects of Urbanization for Streams in the Philadelphia, Pennsylvania Area. Published: U.S. Geological Survey, Water-Resources Investigations Report 87-4194. Retrieved 28th March, 2016.
5. Bryan, A.C. (2002). The Challenges of Stormwater Management. Published: Roads & Bridges, Retrieved 5th March, 2016, from <http://www.roadsbridges.com/challenges-stormwater-management>

6. Enger, E.D., Smith, B.F. & Bockarie A.T. (2006). *Environmental Science: A Study of Interrelationships*. (Tenth Edition), Published: McGraw-Hill Companies Inc., 1221 Avenue of Americas, New York, USA. Pp 288 – 289, 370 – 372.
7. Encarta Dictionary (2009) Published: Microsoft® Encarta® 2009. © 1993-2008 Microsoft Corporation. All rights reserved.
8. Konrad, C.P. (2014). *Effects of Urban Development on Floods*. Published: US Geological Survey, Water Resources, 1201 Pacific Avenue, Suite 600, Tacoma, WA98402. Retrieved 28th March, 2016, from <http://pubs.usgs.gov/fs/fs07603/>.
9. Konrad, C.P. & Booth, D.B. (2002). *Hydrologic Trends Associated with Urban Development for Selected Streams in Western Washington*. Published: U.S. Geological Survey, Water-Resources Investigations Report 02-4040, Retrieved 16th July, 2016, from <http://water.usgs.gov/pubs/wri/wri024040>.
10. Liebl, D.S. (2011). *Stormwater Management and Climate Change: Implications for the Great Lake Regions*. Retrieved 28th March, 2016, from ChangingClimate.osu.edu.
11. Oyeleke, M.A. (2014). *Technology and Geo-Environmental Hazards Monitoring: A Strategic Approach for Flood Disaster Prevention in Nigeria*. Published In: *Proceedings of the 2nd International Conference on Flood and Erosion – Prevention, Protection and Mitigation*. Pg 29 – 44. www.ust.edu.ng.
12. Schueler, T.R. (2000). *The Importance of Imperviousness*. Reprinted in *the Practice of Watershed Protection*. Center for Watershed Protection, Ellicott City, MD.
13. UN-HABITAT (2007). *Global Report on Human Settlements 2007: Enhancing Urban Safety and Security*. Published: United Nations Human Settlements Programme (UN-HABITAT, 2007), P.O. Box 30030, GPO Nairobi 00100, Kenya. www.unhabitat.org. Pp 163-180.
14. U.S. Geological Survey (2003). *USGS Hydrologic Data in and around Mecklenburg County, N.C.* Retrieved 12th March, 2016, from <http://nc.water.usgs.gov/char/>.
15. Amangabara, G.T and Obenade, M. (2015). *Flood Vulnerability Assessment of Niger Delta State Relative to 2012 Flood Disaster in Nigeria*. *American Journal of Environmental Protection*: 3 (3), 70- 83.
16. Ameesha, S.B.; Shashi, M. and Pratap, D. (2017). *A geo-spatial Approach to Flash Flood Hazard Mapping in the City of Warangal, Telangana, India*, *Scienco Environmental Journal*: 3(13), 1-13.
17. Amro, E; Mohamed, A; Ahmed K., Moustafa K., Nassir A., Anis C. and Kashif N. (2019). *Flash Flood Risk Assessment in Urban Arid Environment: Case Study of Taibah and Islamic Universities' Campuses, Medina, Kingdom of Saudi Arabia*. *Journal of Geomatics, Natural Hazards and Risk*: 10(1), 780-796.
18. Barasa, B.N. and Pradeep, E.D.P. (2018). *Analysis of land use change impacts on flash flood occurrences in the Sosiani River Basin, Kenya*. *International Journal of River Basin*: 16(2), 61-82.
19. Belemina, G. (2009). *Disaster Risk: Addressing the Challenge of Natural and Human-Induced Environmental Hazards*. Paris, France Press.
20. Beven, J.K. (2001). *Rainfall – Run-off Modeling*. England: Willey Publisher.
21. Birkmann, J. (2006). *Measuring Vulnerability to Promote Disaster-Resilient Societies: Conceptual Frameworks and Definitions*. *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*. Tokyo, United Nations University Press: 9-54.

22. Bitew, G.T; Mulugata, A.B. and Miegel, K. (2019). Application of HEC – HMS Model for Flow simulation in the bike Tana Basin; The case of GilgelAbay Catchment, Upper Blue Nile Basin, Ethiopia. *Journal of Hydrology*: 2(21), 2-17.
23. Brown, I. and Tari, E. (2017). Towards an effective storm water management in Yenegoa City, Bayelsa State. *Journal of Scientific and Engineering Research*: 4(1), 177-188.
24. Dawod, G.M; Mirza, M.N; and Al-Ghamdi, K.A. (2011). GIS-Based Spatial Mapping of Flood Hazard in Makkali City Saudi Arabia. *Journal of Geographic Information System*: 11(3), 225-231.
25. Debarry, P.A. (2004). *Watershed: Processes, Assessment and Management*. New York. John Willey and Sons.
26. Ede P.N. and Utchay O. (2014). Urban Flood Management Scenarios in Port Harcourt : Proceeding of the 2nd International Conference on Flood and Erosion Prevention, Protection and Mitigation, Nov 2014. (www.ust.edu.ng)
27. El-Basfaxodesy, M; White, K; and Nasr, A. (2009). Integration of Remote Sensing and GIS for Modeling Flash Flood in Wadi Hudien Catchment, Egypt. *Journal of Hydrological Processes*: 23(9), 1359 - 1368.
28. Eyinla, P. and Ukpo, J. (2006). Nigeria: The Travesty of Oil and Gas Wealth Lagos: The Catholic Secretariat of Nigeria.
29. Eze, B.E. and Abua, M.A. (2002). *Environmental Hydrology*. Calabar. Ushie Printers and Publisher Company Limited.
30. Fateye, O.C.A. and Olaschinde, O. B.A. (2016). Mapping Vulnerability of Flash Flood in Ado Ekiti. *Journal of Humanities and Social Sciences*: 21(2), 65-72.
31. Forkuo, E.K. (2011). Flood Hazard Mapping Using Aster Image Data with GIS. *International Journal of Geometrics and Geosciences*: 1(4), 326 – 334.
32. Fubara, M.J.(2014): River Hydrodynamics and Sea Level Monitoring For Flood Impact Control In The Niger Delta, Proceedings of the 2 International Conference on Flood and Erosion Prevention, Protection and Mitigation, November 2014. [www.ust.edu.ng]
33. Ghoneina, E.M; Arnell, N.W. and Foody, G.M. (2002). Characterizing the Flash Flood Hazards Potential along the red sea Coast of Egypt. *The Extremes of the Extremes: Extraordinary Floods (Proceedings of a Symposium held at Reykjarik, Icedand)*.
34. Graf, A. (2014). Spatio-Temporal Relations between water bridge components and soil water content in a forested tributary catchment resource research: 50(6), 60-72.
35. Hapuarachichi, HAP; Wang, Q.J. and Pagano, T.C. (2011). A Review of Advances in Flash Flood Forecasting: *Hydrol. Process*: 25(3), 2771-2784: Retrieved 28/10/2019 from <http://Dx:Doi.org/10:1002/hyp.8040>.
36. Hayder, A.A. & Husam, A.A. (2013). Maximum Likelihood for land use / land cover mapping and change detection using Landsat satellite images: A case study “South of Johor. *International Journal of Computational Engineering Research*, 3(6), 26-33.
37. IMGW, (2013). Institute of Meteorological and Water Management, Report on Plan and Policy Statement.
38. Ismail, E. (2015). 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*: 18(3), 261-278.

39. Leonard, I.U. and Dorathy, I.U. (2013). Gender, Floods and Mental Health. The Way Forward. An International Journal of African Social Sciences: 3(4), 1030 – 1042.
40. Lian, J; Yang, W; Xu, K. & Ma, C. (2017). Flash flood vulnerability assessment for small catchments with a material flood approach. Natural Hazard: 88(2), 699-719
41. Liang, W. Yongli, C; Hongquan, C; Daler, D; Jingmin, Z. and Juan, Y. (2011). Flood Disaster in Talibu basin, China: Causal Chain and Policy Option Analysis Environment and Earth Science: 63(5), 1119 – 1124.
42. Marzieli, S.H; Fateme, Z; Ali, B. and Ali, M. (2014). Flood assessment in the context of sustainable development using the APSIR Framework. International Journal of Environmental Protection and Policy: 2(2); 41-49.
43. Mastin, M. (2009). Watershed Models for Decision Support for Inflows to Potholes. Washington D.C. M.C Grawhill.
44. Mohammed, A.J; Abbas, B; and Abel, A.A. (2016). Spatial Distribution Pattern and Terrain Analysis of urban flash flood and inundation Areas in Maiduguri Metropolis, Borno State, North East, Nigeria.
45. Mohammed, A; Amro, E; Ahmed, K; Monstafa, K; Nassir, A; Anis, C. and Kaslrit, N. (2019). Flash Flood Risk Assessment in Urban Arid Environment: Case Study of Tarbah and Islamic Universities Campuses, Medina, Kingdom of Saudi Arabia (KSA). Journal of Geomatics, Natural Hazards and Risk: 10(1), 780-796. Retrieved on 05/11/2019 from <http://doi.org/10./080/1947505:2018.1545705>.
46. Muneerudeen, A. (2017). Urban Landscape Design Strategies for Flood Resilience in Chennai City: Qatar University: Doha Patar.
47. National Emergency Management Agency (NEMA) (2012) Report on Flood Disaster.
48. NPC, (2006). National Population Commission Report for 2006 Census Exeecial.
49. NPC, (2019). National Population Commission Annual Projection 2019 for cities and staets in Nigeria.
50. Odeyemi, C.A. & Olabode, B.A.D. (2016). Mapping Vulnerability to Flash Flood in Ado-Ekiti. JOSR Journals of Humanities and Social Sciences: 21(2)65-72
51. Olabode, B.J. (2014). Impact of River Niger Flooding on the Inhabitants of Lokoja and its Environs: International Conference on Flood and Erosion Prevention, Protection and Mitigation. November, 2014.
52. Ologunorisa, T.E. and Abawua, M.J. (2005) . Flood Risk Assessment: A Review Department of Geography, Benue State University, Makurdi. Journal of Applied Sciences and Environmental Management and Mitigation Options for Nigeria: Proceedings of the 2nd International Conference on Flood and Erosion Prevention, Protection and Mitigation, November, 2014.
53. Olowu, D. (2010). The Hyogo Framework for Action and its implications for Disaster Management and Education in Africa. JAMBA: Journal of Disaster Risk Studies, 3(1):303-320
54. Oyebande, L.(2014).Integrated Flood Management and Mitigation options for Nigeria: Proceedings of the 2nc International Conference on Flood and Erosion Prevention, Protection and Mitigation, November 2014.
55. Oyegun, C.U. (1994). Geology and Sedimentary Environment in Oyegun and Adeyemo (e.d) Port Harcourt Region. University of Port Harcourt Publication series No. 1.

56. Oyegun, C.U. (2003). *Essentials of Social and Environmental Research*, Port Harcourt: University of Port Harcourt.
57. Pagano, T. and Sorooshian, S. (2002). Hydrologic Cycle. *Encyclopedia of Global Environment Change*.
58. Subramanya, K. (2008). *Engineering Hydrology*, New York, McGraw Hill Press.
59. Sunmin, L; Saro, L; Moungh-Jin, L. and Hyund-Sup, L. (2018). Spatial Assessment of Urban Flood Susceptibility Using Data Mining and Geographic Information System (GIS) Tools. *Sustainability Journal*, 10(3), 648-655.
60. Uchenna, E.O. (2013) Perception of flood Disaster risk reduction and Adaptation Strategies in Port Harcourt Metropolis. M.Sc thesis, department of Geography and Environmental Management University of Port Harcourt.
61. Umeuduji .J.E (2010) *Drainage Basin Dynamics*, Ehai Books, Published in Nigeria, University of Port Harcourt
62. UN, (2009). *United Nations World Water Development Report 3. Water in a changing world*. The United Nations Educational Scientific and Cultural Organization (UNESCO).
63. Weli, V.E (2004) *Urban Flood Prediction in the Niger Delta. A case study of Port Harcourt metropolis*, M.sc Thesis Submitted to the department of geography and environmental management, university of Port Harcourt
64. Woubet, G.A. and Belachew, D.L. (2011). *Flood Hazard and Risk Assessment Using GIS and Remote Sensing in Fogera Woreda, Northwest Ethiopia*. Department of Natural Resources Management, Blaire Dar University Blaire Dari, Ethiopia.
65. Youssef, A.M; Pradhan, B; and Sefry, S.A. (2016). Flash flood susceptibility Assessment in Jeddah City, Kingdom of Saudi Arabia, using Bivariate and Multivariate Statistical Models. *Journal of Environmental Earth Science*: 75(12), 161 – 182.