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An Assessment of Flood Vulnerability in Selected Urban Catchment: A Case Study of Port Harcourt Metropolis, Nigeria

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Abstract: Flooding occurs due to increase in global temperatures high rate of precipitation and increase rate of runoff and increase rate of urban flooding. The aim of study is to determine the flood risk assessment of selected urban catchment in Uyo metropolis, Nigeria. The study adopted correlational research design where secondary data was generated from Landsat Imageries of the study area. The digital elevation model of the area was used to determine the water shed pattern, landuse/landcover and inundation level using supervised classification of landuse in the area. The study also adopted Geographic Information System (GIS) aided computer simulation of the storm water been generated through enhanced DEM to determine storm water level and inundation based on landuse/landcover change. Data generated was analysed using hydrological models and techniques which includes storm water generation assessment, inundation modeling, assessment of land cover and level of inundation and evaluation of flash flood vulnerability using modeled inundation. Findings showed that Uyo has a number of streams of different flow lengths which was lower. The study also revealed that Uyo has 21 sub basins. The total runoff in uyo was higher (0.74) inches Also the rate of change of in catchment behaviour like the catchment precipitation, node flooding and runoff in Uyo continued to increase with time of the day, and the rate of change of volume of runoff varied slightly. The width of hydrograph was not wider as the areas prone to moderate and high flood in Uyo metropolis was higher (78.03%). Based on these findings, the study recommends that better planning of the cities is required to regulate the effect of flooding in the study area. The area liable to moderate and high flood vulnerability should be well monitored and guarded to minimize the destruction of lives and properties.

Keywords: Catchment, Flood, Urban, Vulnerability

Introduction

The increase in global temperatures, seasonal shifts, and high rate of precipitation which lead to increase rate of run-off increases the rate of urban flash flood (Sunnin, Saro, Moung-Jin and Hung-Sup, 2018). Heavy rains, typhoons, floods and other meteorological conditions cause variation in the hydrological system and increase the pressure on drainage systems, water works,, and sewage facilities in urban areas (Muneerudeen, 2017). Subsequently, with high concentrations of rainwater in rivers, flooding risk increase substantially.Flash flood is generally defined as a rapid onset of flood with a short duration and a relatively high peak discharge (Ismail, 2015). Flash flood occurs rapidly, generally within one hour of rainfall and

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sometimes accompanied by landslides, mud flows, bridge collapse, damage to buildings, and facilities (Hapuarachichi, Wang & Pagano, 2019).

In most recent years, a flood occurrence can be forecasted by applying hydrologic and hydraulic models, which needed large-scale data that are not accessible. Aneesha, Shashi and Meshapam (2019), have noted that the utilization of Geographic Information System (GIS) based tools for flood risk and hazard evaluation was uncommon before 2000. Therefore, it is of high importance for city and urban planning professionals to map and manage the natural risk cause by flash floods for future planning. With the advent and development of computer, disaster management and mitigating authorities can now predict where flood will occur and how severe they are likely to be with an amazing accuracy. So far and in recent times, many studies have been done to map flood in different countries to determine the level of flash flood and the inundation level to produce the flood hydrographs and flood maps to show the level of hazard as a result of the run-off as in the United States (Mastin, 2009), China (Liang, Yongli, Hongquan, Daler, Jingmin and Juan, 2011), Egypt (El Bastawesy, White and Nasr, 2009; Ghomein, Arnell and Foody, 2002), Saudi Arabia (Sand, 2010; Dawod, Mirza & Al-Ghandi, 2011), India (Bhatt, Rao, Manjushree and Bhanumurthy, 2010) & Ghana (Forkuo, 2011).

Flood simulation models have wide variety of approaches that are available to compute the water surface elevation associated with flood events. Some of these models use a one Dimensional approach (ID), others use a two-Dimensional (2D), and there are others that allows the use of integrated ID and 2D simulation. However, in 2015, the US Army Corps of Engineering Hydrologic Engineering Center (HEC) released HEC-RAS version 5.0.3 which perform ID steady and unsteady calculation as well as 2D and unsteady flow calculation to determine flash flood using the HEC-RAS model. Other models that are used to examine flood hazards include HEC-HMS model, Digital Elevation Model (DEM) and land satellite images across urban centres.

In the Niger Delta region of Nigeria like other deltaic regions of the world, flash flood is a common hazard. This is because most places in the region lie below sea-level. The deltaic nature of the drainage basin in the region, and the fact that the entire area lies within the flood as well as the increasing urban population pressure on the urban landscape of the area without proper land use planning has made the region flash flood prone. In the wake of increased land use and land cover change, increased human developmental activities and intense rainfall and the high rate of runoff there is serious concern to examine the incidence of flash flood in the area. Given the study on flash flood risk assessment in Niger delta city is carried out in a selected urban centres in the area.

Basically, Uyo metropolis are selected for this study because of the fact that these two cities have gluts of swampy basins cross-crossed by myriad of rivers and creeks (Amangabara and Obenade, 2015 and Eyinla and Ukpo, 2006) which laze directly in the wet equatorial climatic belt, because the qua river, Ibew rivers and the Itu river and other creeks, and streams drain the Uyo metropolitan area (Amangabara & Obenade, 2015).

Secondly, Uyo metropolis was chosen for this study because of their high urban population size which makes these cities vulnerable to flash flood. The National Population Commission (NPC) (2019) puts the population figures of Uyo in 2019 as 1,773,000, Yenegoa in 2019 as 470,800, Benin city in 2019 as 1,676,000, Calabar in 2019 as 555,000, Asaba in 2019 as 407,126 and Warri in 2019 as 814,000. Therefore, Uyo metropolis which often experienced flash flood has been a source of worries to urban planners.

Flash flood in recent time has caused devastating effect in urban areas resulting to loss of lives, destruction of property and displacement of millions of people. Current evidence and observation have shown that the occurrence of urban flash flood is as a result of increased urbanization; landuse and land cover changes, uncontrolled development, human attraction and encroachment of flood plains and wetlands, and the blockage river channels, divides and drainages. The lack of proper delineation of potential flash flood and inundation area to produce flash flood and inundation area to produce flood maps to show the actual extent of inundation of flood plain is a serious problem. The issue of poor landuse control and improper urban planning, lack of knowledge of landuse and land cover changes and dearth of expertise in the application of GIS in modeling flash flood risk assessment also exacerbate the problem.

To facilitate the goal of the study the following research questions are past forward.

1. How does storm-water generation vary across each of the cities under consideration?

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2. What is the potential level of inundation due to flash flood across the study area?
3. How does land use and cover affect the inundation levels across the study area?
4. What is the pattern of flash flood vulnerability across these areas?

Aim and Objectives of the Study

The aim of the study is to determine flood vulnerability of selected catchments in Uyo, Nigeria. The specific objectives are to:

1. model the variation in storm-water generation across each of the cities in the study area.
2. model potential level of inundation of flash flood across the cities of the study area.
3. analyze level of inundation of flash flood on land use /cover across the cities.
4. model the vulnerability of selected urban catchment to the pattern of flash flood in the area.

Study Area

The study area for this research is Uyo Metropolis located within latitude $4^0$32'N to 5^o33'N of the equator and longitudes 7^o25'E to 8^o25'N of the Greenwich Meriden (Census, 2006). Uyo is the capital of Akwa Ibom State. Uyo metropolis has a population of 427,873 (NPC) and an estimated population of 7124440 (2019 Population Estimate). It has a total area coverage of 362km^2 and a density of 1,200km^2 (1,300/sqm).

Climate

Uyo metropolis has a unique typical climate, the climate condition of Uyo is 26.4^{o}C and annual rainfall averages 250gmm (Oyegun, 1994). The relief and drainage of the study area is such that the area falls within the coastal belt dominated by low lying coastal plans which structurally belong to the Agbada and Akata formulations. The area is low lying costal thereby making the flow of water and surface runoff to have hitches in its flow pattern. The monotonously flat landscape comprises of coastal plains criss-crossed by a labyriath of swamp, creeks and water ways, indicating a relatively scarcity of firm and extensive land mass. The soil and geology of the area consists of various types of super final deposits overlying thick tertiary sandy and clayey deposits which are over 100m thick in places. The consistently high rainfall and temperature of the area encourage intense chemical weathering of the rocks, which result in the formation of clay minerals that are ubiquitous in the region (Oyegun, 1994). The area is made of two broad groups of soil derived from the sediments and those formed on younger quaternary and recent alluvium.

Methods of Data Collection

The data for the study was collected using Geographic Information System (GIS) aided computer simulation from United States Geologic Survey (2020). The storm water was generated across the study area through enhanced DEM developed for the area to show the level of inundation based on land cover, watershed delineation and participation also captured the vulnerability level of the inundated area.

This study also adopted the research design. The correlational design approach is being used in this study and is aimed at measuring the strength of the relationship between runoff (stormwater) and the associated risk of vulnerability (inundated impact) on flood prone areas in the study area. Hence, data for the study is secondary data generated from landsat imageries of the study area showing the digital elevation of the area and the water shed pattern, the landuse and landcover maps forms a supervised classification of landuse in the area.

Method of Data Analysis

The data for this study was analyzed using hydrological models and modelling techniques to achieve the objective of the study .

1. **Storm water Generation Assessment: To model storm water generation in the small catchment, the flood hydrograph modelling was done using the following steps:**
   a) Get the Dem data for the study area
   b) Run a model using the DEM data on GIS software to slow the storm water generated.
   c) Weigh and overlay 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.

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d) Produce the volume of the runoff which is plotted to show the flood hydrograph. Thus, this technique was adopted by Amro et al (2019) in assessing flash flood risk in urban catchment in Taiah and Islamic University Campus of Kingdom of Saudi Arabia.

2.Inundation Modeling

Watershed/catchments modeling was used to delineate the catchment/watershed and carry out hydrological modeling using soil, climate, elevation, drainage data for the study area in order to measure the potential level of inundation of flash flood across cities. The GIS Software will be used to model rainfall runoff across the study area, in this current study as adopted by Amro et al (2019) and Lian et al, (2017), will be applied to delineate the catchments across the cities. This will show the inflow of flood and runoff simulation and potential level of inundation in the study area.

3.Assessment of Relationship between Land Cover and level of Inundation

The following steps were taken:

(a) Get the land cover of the cities
(b) Recreate inundation level of material flow to land covers.
(c) Compare inundation level based on land cover.

4.Evaluation of Flash Flood Vulnerability using Modeled Inundation

Vulnerability assessment will be carried out using Jenk's classification based on the level of inundation modeled. Areas would be classified into 5 groups: Very High (VH), High (H), Moderate (M), Low (L) and Very Low (VL) vulnerability classes. The cities would be partitioned into hydrological segments. Each hydrological unit would be partitioned into small catchments/watershed units and the catchments/watershed units will be partitioned into hydrological response unit (HRUs) and proportions of different land use and land cover will be derived. This was adopted by Woubet and Belachew (2011) to assess flood hazard and risk assessment using GIS and remote sensing in Fogera Woreda, northwest Ethiopia.

Results and Discussion

Storm water generation in Uyo metropolis total length of streams was 312894.25m and the average length was 1246.59m. There were 251 streams that were found in Uyo metropolis and the highest flow length was 0.14m.

Table 1: Stream Parameters

Stream Parameters	Uyo
Total Stream Length (m)	312894.25
Average Stream Length (m)	1246.59
Number of Streams	251
Standard Deviation	469.16
Minimum (m)	460.64
Maximum (m)	3261.87
Highest Flow Length (m)	0.14

Source: Researcher Analysis, 2020

In Uyo metropolis, the area of sub-basin ranged from 1187688.18 to 92699584.59sqm with the mean value of 11845065.10sqm.

Table 2: Stream Parameters

Sub Basin Parameters	Uyo
Total Number of Basins	21
Total Area (Sq. m)	248746367.20
Minimum (Sq. m)	1187688.18
Maximum (Sq. m)	92699584.59
Average Area (Sq. m)	11845065.10
Standard Deviation (Sq. m)	19630077.58

Source: Researcher's Analysis, 2020

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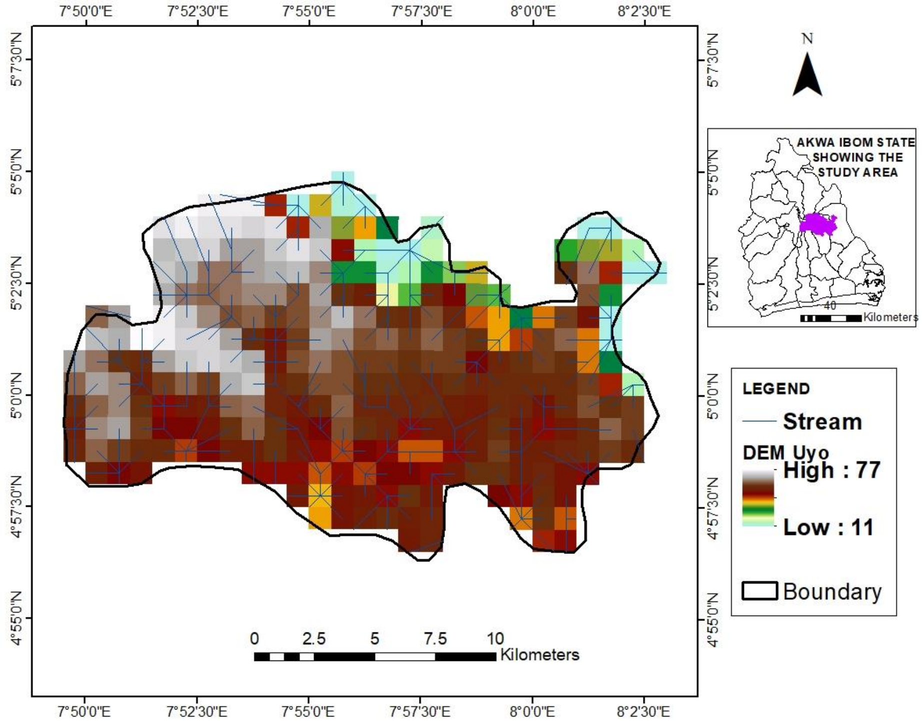

Fig. 1: DEM of Uyo and Streams

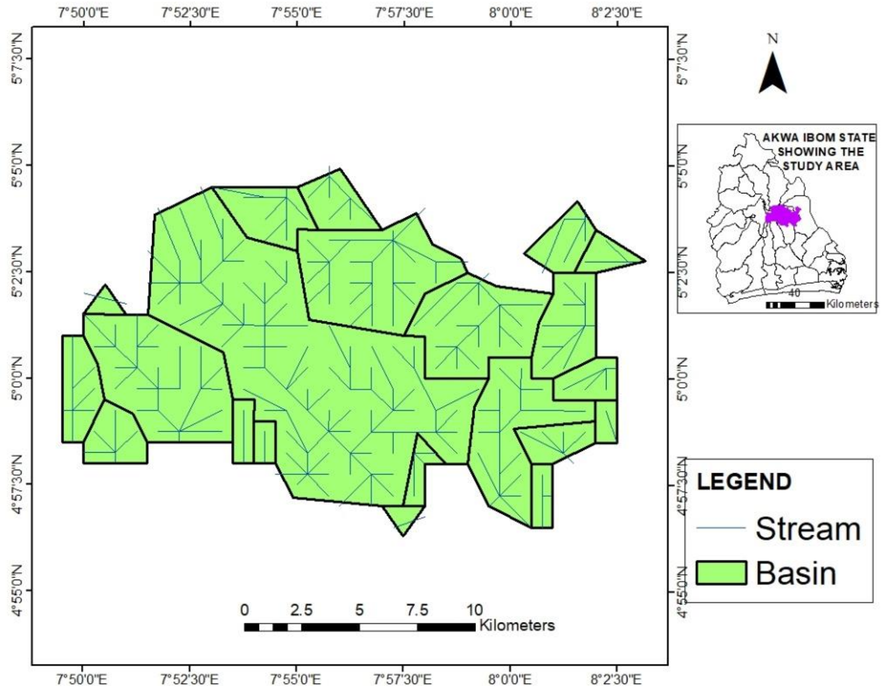

Fig. 2: Streams and Basins

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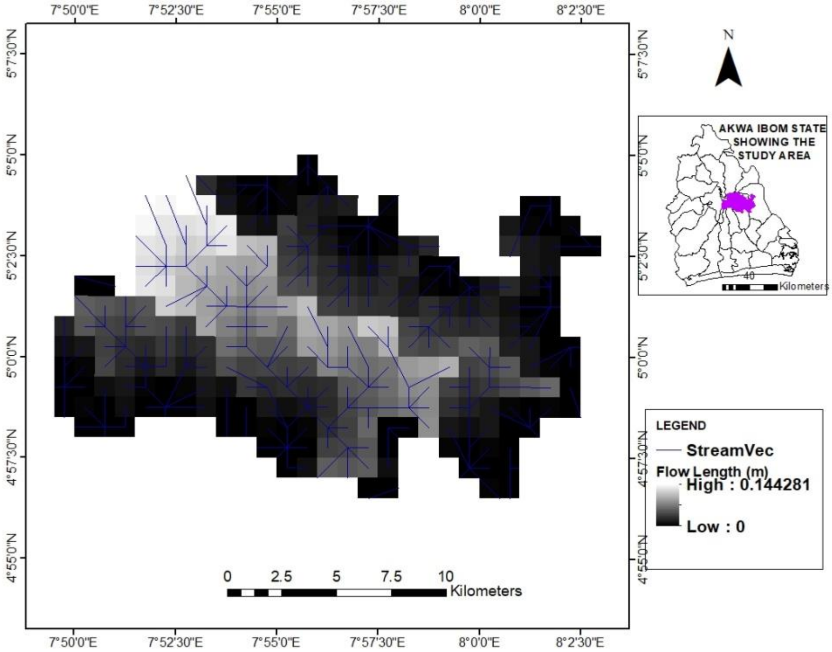

Fig. 3: Flow length of Flood in Uyo Metropolis

Storm Water Generation in Uyo Metropolis

Based on the study objectives which includes to analyze the probability of occurrence and variation of stormwater generation in the study areas the results in

Table 4.8 shows the simulated sub catchment runoff in Uyo Metropolis whereby 8 sub catchments were used for the runoff generation (Figure 4.11). It is clearly shown that the total precipitation in each of the sub catchment is similar which was 0.03 inch while the total infiltration read 0.01 inches. The total runoff was 0.02 x 10^6 gal and peak runoff was 0.01 x 10^6 CFS.

The link flow analysis through the conduit or pipe as shown in Table 4.9 reveals that the range of maximum flow of the conduit was from 0.01 CFS in C1, C3, C5 and C7 to 0.04 CFS in C2 and C6 while hour of flow was 6 hours. It is thus observed that the conduits had maximum velocity ranging from 0 ft/sec in C1 to 49 ft/sec in C6. The maximum full depth of the conduit appeared to range from 0 ft (C1) to 0.04 (C8).

The outfall loading shown in Table 4.7 revealed that the flow frequency was 45.56% while the average flow was 0.03 CFS. The maximum flow was 3.64 CFS and total volume of storm water was 0.05 x 10^6 gal in Uyo Metropolis.

Table 3: Sub-catchment Runoff in Uyo

Sub catchment	Total precipitation (in)	Total Runon (in)	Total Evaporation (in)	Total Infiltration (in)	Impervious Runoff (in)	Pervious Runoff (in)	Total Runoff (in)	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
S1	0.03	0	0	0.01	0	0.01	0	0.02	0.01	0.095
S2	0.03	0	0	0.01	0	0.01	0	0.02	0.01	0.095
S3	0.03	0	0	0.01	0	0.01	0	0.02	0.01	0.095
S4	0.03	0	0	0.01	0	0.01	0	0.02	0.01	0.095
S5	0.03	0	0	0.01	0	0.01	0	0.02	0.01	0.095
S6	0.03	0	0	0.01	0	0.01	0	0.02	0.01	0.095
S7	0.03	0	0	0.01	0	0.01	0	0.02	0.01	0.095
S8	0.03	0	0	0.01	0	0.01	0	0.02	0.01	0.095

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Table 4: Link Flow in Uyo

Link	Type	Maximum Flow (CFS)	Day of Maximum Flow	Hour of Maximum Flow	Maximum Velocity ft/sec	Maximum/ Full Flow	Maximum Full Depth
C1	CONDUIT	0.01	0	6:00	0	0	0
C2	CONDUIT	0.04	0	6:00	4.07	0	0.03
C3	CONDUIT	0.01	0	6:00	1.15	0	0.02
C5	CONDUIT	0.01	0	6:00	2.3	0	0.02
C6	CONDUIT	0.04	0	6:00	4.9	0	0.03
C7	CONDUIT	0.01	0	6:00	1.15	0	0.02
C8	CONDUIT	0.02	0	6:00	1.24	0	0.04

Table 5: Node Inflow in Uyo

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Day of Maximum Inflow	Hour of Maximum Inflow	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal	Flow Balance Error Percent
J1	JUNCTION	0.01	0.01	0	6:00	0.000302	0.000302	0
J2	JUNCTION	0.01	0.04	0	6:00	0.000302	0.00203	0
J3	JUNCTION	0.01	0.04	0	6:00	0.000302	0.0023	0
J4	JUNCTION	0.01	0.01	0	6:00	0.000302	0.000302	0
J5	JUNCTION	0.01	0.02	0	6:00	0.000302	0.000879	0
J6	JUNCTION	0.01	0.01	0	6:00	0.000302	0.000302	0
J7	JUNCTION	0.01	0.01	0	6:00	0.000603	0.000603	0
Out1	OUTFALL	0	0.04	0	6:00	0	0.00228	0

Table 6: Node Depth in Uyo

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Day of Maximum Depth	Hour of Maximum Depth	Maximum Reported Depth Feet
J1	JUNCTION	0	0	255.91	0	6:00	0
J2	JUNCTION	0.02	0.04	226.42	0	6:00	0.04
J3	JUNCTION	0.01	0.03	180.48	0	6:00	0.03
J4	JUNCTION	0.01	0.02	236.24	0	6:00	0.02
J5	JUNCTION	0.02	0.04	229.7	0	6:00	0.04
J6	JUNCTION	0.01	0.02	236.24	0	6:00	0.02
J7	JUNCTION	0.01	0.02	252.65	0	6:00	0.02
Out1	OUTFALL	0.01	0.03	111.58	0	6:00	0.03

Table 7: Outfall Loading in Uyo

Outfall Node	Flow Frequency (%)	Avg Flow (CFS)	Maximum Flow (CFS)	Total Volume (10^6 gal)
Out1	45.56	0.03	0.04	0.05

Sub Catchment Precipitation, Node Flooding and Linking Volume

However, the rainfall time series in Uyo Metropolis in Figure 4.13 started to rise from 0 hours till it reached the peak at the 18^{th} to 20^{th} hours of the day before it continued to decrease.

The behaviour of sub catchment situations with respect to precipitation runoff, infiltration, node flooding and link volume at different hours of the day is captured Table 4.13, Figure 4.13 (0.0-0.45 mins),

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Figure 4.14 (1.00mins-01.15mins), Figure 4.15 (1.15mins-04.00mins) and Figure 4.16 (04.00-06.00mins). The analysis showed that the sub-catchment precipitation continued to increase with increasing time of the day from 0 in to 0.39 in. Also, the flooding and linking volume through the day had similar trend although at different hours of the day. For instance, the node flooding started to increase at 0.15mins (25 CFS) and the flooding volume increased to 75 CFS at 1.00 mins while the linking volume ranged from 0 ft^3 to 460 ft^3. For Uyo Metropolis, it is found that the sub-catchment precipitation, node flooding and linking volume observed in Figures 4.18 and 4.19 and Table 4.14. The analysis revealed that sub catchment precipitation and node flooding increased abruptly at 3 hrs.00 mins from 0.01 in to 0.05 in and 25 in to 50 in respectively.

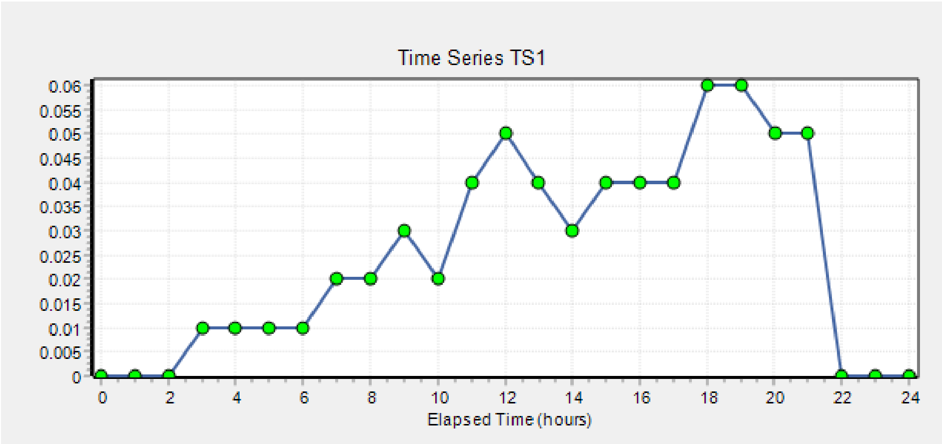

Fig. 4: Time Series of Precipitation Data in Uyo

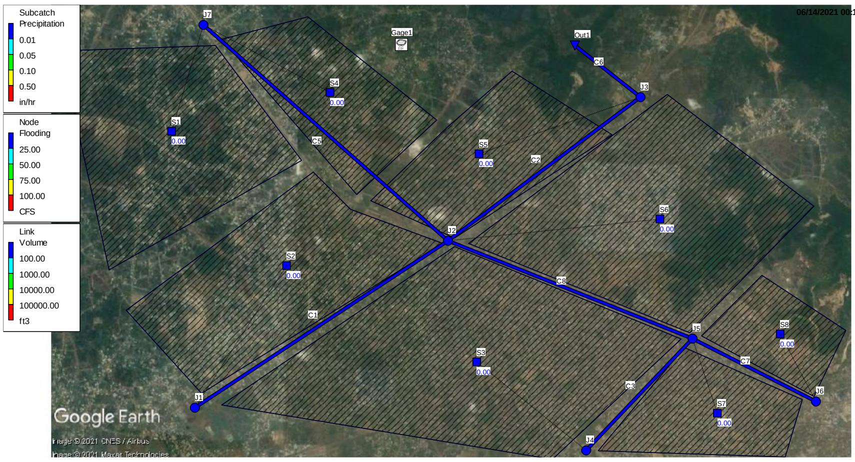

Fig. 5: Sub Catchment precipitation, Node Flooding and Link Volume in Uyo at 0.00 mins – 03.00 Mins

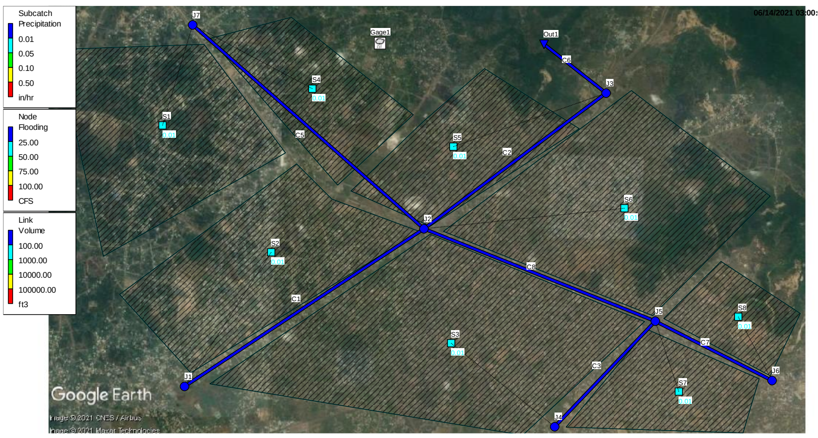

Fig. 6: Sub Catchment precipitation, Node Flooding and Link Volume in Uyo at 03.00 mins – 06hour.00 Mins

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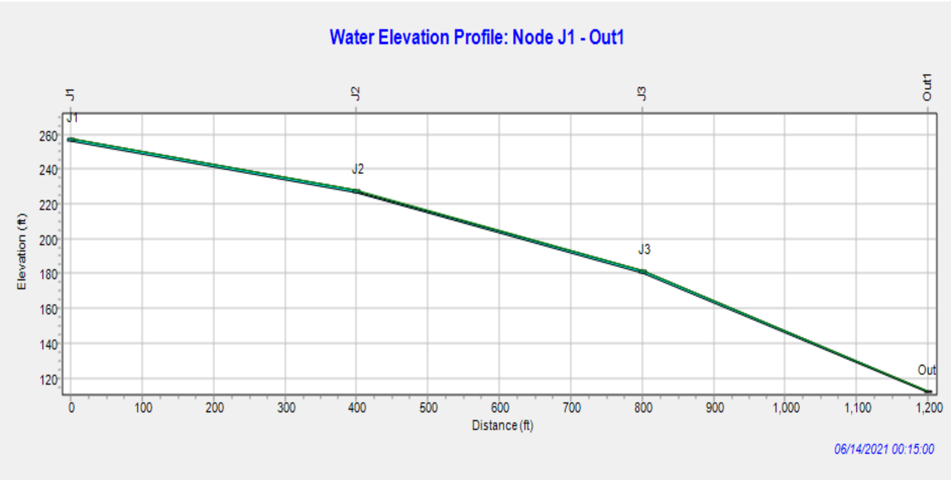

Fig. 7: Water Elevation Profile from Node 1 – Out 1 in Uyo

Flood Vulnerability in Uyo Metropolis

Landuse Map Vulnerability

The landuse map vulnerability to flood was determined according to the vulnerability levels assigned to each landuse identified in Uyo Metropolis. Table 4.24, Figure 4.45 and Figure 4.46 explain the types of landuse discovered and the spatial extent of each of them. The built up area had the highest spatial extent (141783308.91 m^2), followed by vegetation patches having 50813320.29 m^2. The analysis also revealed that farmlands/Sparse vegetation recorded 35785889.00 m^2 while waterbodies had 26428311.14 m^2. The built up area covered 55.64%, farmlands/sparse vegetation covered 14.04% while waterbodies and vegetation patches 10.37% and 19.94% respectively. The analysis further showed that the spatial extent of the area for moderate flood vulnerability was 33.98% while high flood vulnerability was 66.02%.

Table 8: Landuse Classification in Uyo

Landuse	Area (Sq. m)	Percentage (%)	Vulnerability Rank	Vulnerability Interpretation
Waterbodies	26428311.14	10.37	3	High
Farmlands/Sparse Vegetation	35785889.00	14.04	2	Moderate
Built	141783308.91	55.64	3	High
Vegetation Patches	50813320.29	19.94	2	Moderate
Total	254810829.3	100.0		

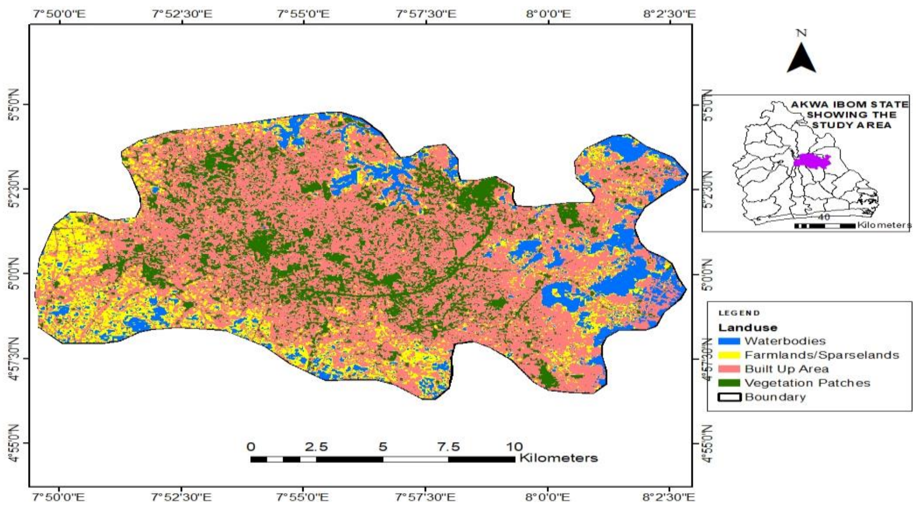

Fig. 8: Landuse/Land cover of Uyo Metropolis

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Flood Vulnerability Map based on Elevation

The flood vulnerability level based on elevation is shown in Table 4.25, Figure 4.47 and Figure 4.48. It shows that the high vulnerability zone based on elevation was between 11m and 39m while the moderate vulnerability was between 40m and 59m. Areas highly flooded in Uyo includes; Udo Eduok street, Abak Road, IBB way, Afiansit, Ibom Arena and Ikot Ekpene Road. The low vulnerability zone was between 60m and 77m. The analysis also revealed that the high, moderate and low vulnerability covered 160527854.17 m^2 (64.45%), 73497488.63 m^2 (29.51%) and 15056611.64 m^2 (6.04%) respectively.

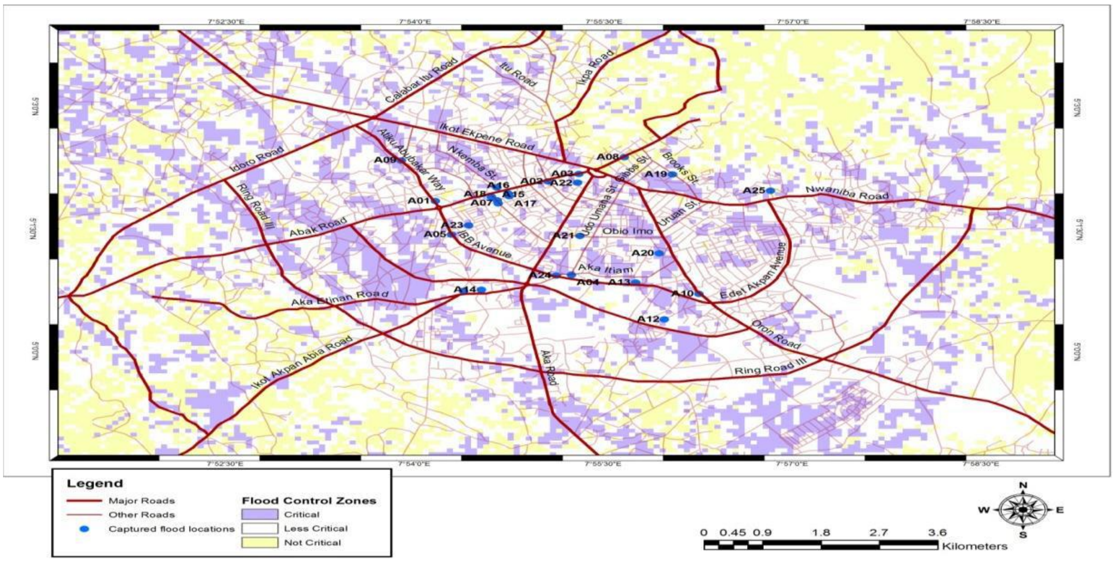

Fig. 9: Highly Flooded zones in Uyo Capital City

Table 4.24: Elevation data of Uyo Metropolis

S/n	Elevation (m)	Spatial Extent (m^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
1	11-39	160527854.17	64.45	3	High vulnerability
2	40-59	73497488.63	29.51	2	Moderate vulnerability
3	60-77	15056611.64	6.04	1	Low vulnerability
	Total	249081954.4	100.00		

Source: Researcher's analysis, 2021

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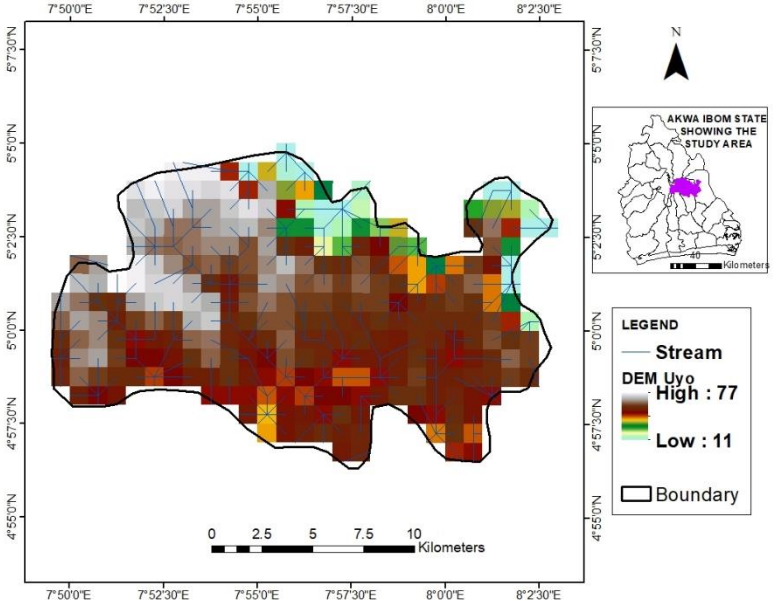

Fig. 10: Elevation of Uyo Metropolis

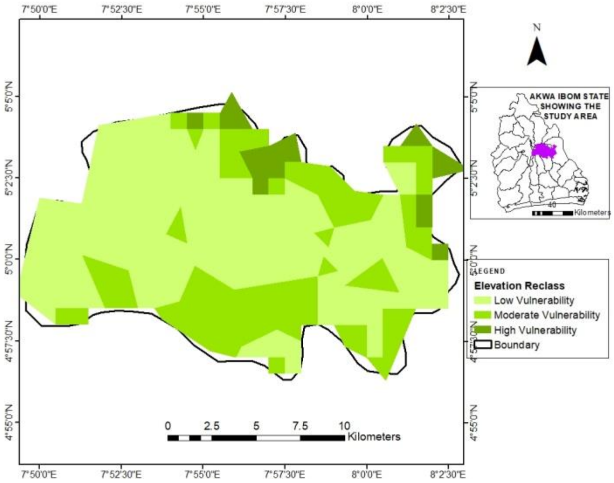

Fig. 11: Elevation Vulnerability of Flood in Uyo

Soil Texture Vulnerability Map

Table 4.26 and Figures 4.49 and 4.50 describe the soil texture vulnerability to flood of Uyo. The analysis showed that the coarse texture covered 15167602.96 m^2 while fine texture covered 239643226 m^2. This shows that 94.05% and 5.95% was for high vulnerability and low vulnerability respectively.

Table 10: Soil vulnerability of flood in Uyo Metropolis

S/n	Soil Texture Type	Spatial coverage (m^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
1	Coarse Texture	15167602.96	5.95	3	High vulnerability
2	Fine Texture	239643226	94.05	1	Moderate vulnerability
Total		254810829	100.00		

Source: Researcher's analysis, 2021

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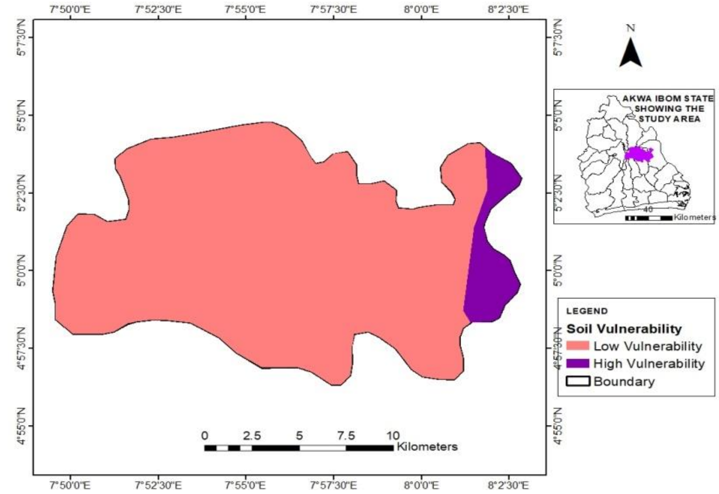

Fig.12: Soil Texture of Uyo Metropolis

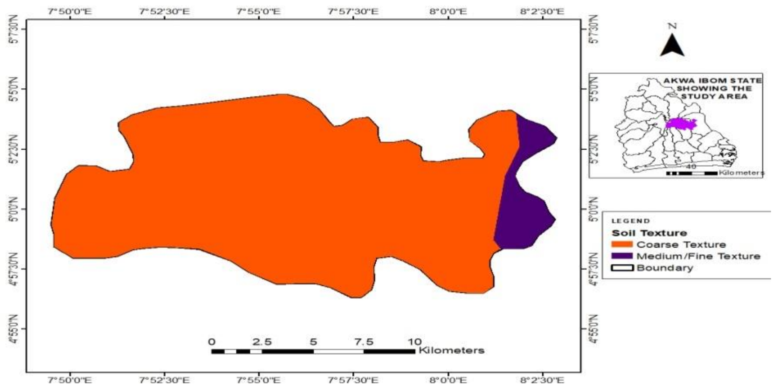

Fig.13: Soil Texture Vulnerability Level to Flood in Uyo

Proximity to River Channel (Drainage) Vulnerability Map

Table 4.21 and Figures 4.51 and 4.52 describe the drainage buffering and drainage vulnerability maps of Uyo respectively. The results show that the buffer of 200m from the rivers (i.e., high flood vulnerability level based on the proximity to active channel) covered a spatial extent of 57379846.66 m^2 (20.46%); the buffer of 400m which was regarded to be moderate vulnerability covered 1033867512.24 m^2 (37.04%) while the buffer of 600 m known to be low vulnerability covered a spatial extent of 119137260 m^2 (42.49%).

Table 11: Drainage vulnerability of flood in Uyo Metropolis

S/n	**Buffer Scenarios (m)**	**Spatial coverage (m^2)**	**Percentage (%)**	**Vulnerability Assigned Values**	**Vulnerability Levels**
1	0-200	57379846.66	20.46	3	High vulnerability
2	200-400	103867512.24	37.04	2	Moderate vulnerability
3	400-600	119137260	42.49	1	Low vulnerability
Total	Total	280384619.00	100.0		

Source: Researcher’s analysis, 2021

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Discussion of Findings

However, the average stream length was lower in Uyo Metropolis. Considering the number of sub basins in the study area, findings showed that Uyo had 21 sub basins.

The sub catchment runoff, Node flooding and link velocity of 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 figure 4.27 (1.30mins – 6.00mins). 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. in Uyo metropolis. 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 runoff 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 three different water elevated profiles were generated. 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. The water elevation profile in Uyo metropolis included the node 1 – out 1 (figure 4.33) node 6 to out 1 (figure 4.34), node 7 to out 1 (figure 4.35). All of them continue to decrease in elevation with increasing distance to outfall except the one in Node 6 to out 1.
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. Looking at Table 4.18, figure 4.36 and figure 4.37 explained 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%.

In Uyo metropolis, the flood vulnerability according to the analysis and finding revealed that vulnerability levels assigned to each landuse identified in Uyo metropolis. According to Table 4.24, Figure 4.45 and figure 4.46 explained the types of landuse discovered and the spatial extent of each of them, buildup area (141783308.91m^2) vegetation patches (50813320.29m^2). The findings revealed farmland /space vegetation recorded 35785889.00m^2 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 in Uyo Metropolis. 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 21 sub basins. Hence the total area of the basin was lower in Uyo, although the average area of the basin was higher in Uyo. The digital elevation is lower in range in Uyo. For Uyo, it ranged between 11m and 77 m.

In Uyo the flow frequency is lower and also the total volume of storm water. 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 in Uyo. The width of the hydrograph in Uyo not wider. The areas prone to moderate and high flood in Uyo was 78.61%.

Conclusion

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

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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 are found
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

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