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Assessment of Flood Risk and Mapping of Flood Risk Zones in Yenagoa, Bayelsa State, Nigeria

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ABSTRACT: In recent years, most Nigerian cities have experienced several major flood episodes with serious catastrophes. Hence, this study was carried out to assess and map flood risk zones in Yenagoa. The Geographic Information System (GIS) and remote sensing technologies were used in generating and analyzing data to identify the different flood risk zones in Yenagoa. Environmental indices such as flood heights, land elevation and land cover images were analyzed using geo-statistical tools such as map overlay operations to produce a flood risk map. The flood risk map produced and the ground truthing carried out confirmed that the highest flood risk are located within residential areas where about 32% of the built-up area was vulnerable to moderate or high risk of flooding. The study revealed that both natural and anthropogenic factors are responsible for the severe flooding experienced in Yenagoa, especially due to heavy precipitation, elevation of the area, poor waste disposal, and inadequate urban development control amongst other factors. The city was classified into three flood risk zones-high, moderate and low, with about 48% of the area being either at moderate or high risk of flooding. It is therefore recommended that the Ministry of Physical and Urban Development should carryout proper urban development control, which will prevent building on flood plains, wetlands and natural drainage channels.

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Flood is one of the major natural hazards that have constituted serious challenges in almost every continent of the world. The rate, intensity and severity of floods seem to be increasing with the passage of each year, probably as a result of climate change. In the past, studies have focused heavily on understanding the causes and impacts of flood hazards across the world (Adeoye *et al*, 2009; Odufuwaet *et al*, 2012; Odubo, 2014). In recent years, however, much attention is now being paid to flood risk analysis and assessment, as it is a critical step in hazard management, which involves the identification of flood spots, the determination of the level of damage a flood event would have and the development of strategies and policies for better risk management. One of the most reliable and efficient techniques for conducting flood risk analysis and mapping of an area is the geographic information system (GIS), which is a computerized method of data acquisition, analysis and presentation. This technique has been deployed by different studies for spatial analysis of flood risk and vulnerability in different parts of Nigeria (Amangabara and Obenade, 2015; Ugoyibo *et al*, 2017;Berezi *et al*, 2019; Tomar *et al*, 2021; Allafta and Opp, 2021). The outcomes of some of these studies have proven dependable for flood policy direction and the development of strategies and measures for the management of flood prone areas. Hence, this study adopted the GIS technique to analyze flood risk and mapping of vulnerable areas in Yenagoa. This will reveal areas in the city that are more vulnerable and at great risk of flooding, which will assist in focused mitigation interventions by government agencies and reduce the associated challenges of flooding in the city. The rate of population growth and economic activities in Yenagoa has been increasing steadily since 1996 when it was named the capital city of Bayelsa State. The rich deposit of crude oil and natural gas in the state has made it to be of huge economic importance to Nigeria, attracting different classes of people from different walks of life to the city, which is now recognized as one of the fastest growing cities in

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Nigeria. However, the location of Yenagoa in the Niger Delta region, where high precipitation is experienced with many creeks and streams crisscrossing the area, has made it to be highly susceptible to flooding, especially urban flash floods, which are usually associated with torrential rainfall and annual rise of the Epie and Ekole Creeks. Hence, any major flood event would constitute serious havoc to properties and huge economic loss to both the government and the citizens. The high population growth rate and increasing socioeconomic activities in Yenagoa, exposes more people to the risk of flooding due to poor urban development control. Therefore, there is the need to assess the city's flood risk level in order to develop policies for risk reduction in line with the Sendai declaration. One of the best ways to achieve this is by flood mapping which will help in the identification of the areas that are at risk and elements that are exposed to flood hazard in Yenagoa. Therefore, the aim of this study is to conduct an assessment of flood risk and mapping of flood risk zones in Yenagoa

MATERIALS AND METHODS

Description of the Study Area: "Yenagoa is located in the Niger Delta region of Nigeria and capital of Bayelsa State. It lies between latitudes 4° 55' and 5° 02' north of the Equator and longitudes 6° 15' and 6° 25' east of the Greenwich meridian (Figure 1)" (Ohwo, 2019). The population of Yenagoa has been growing rapidly since 1996 when it became the capital of Bayelsa State. The population has increased from about "50,000 people in 1991 to about 350,000 in 2019" (Ohwo, 2021). Yenagoa experiences Equatorial climate, with two distinct seasons, dry and wet. The dry season is dominant from the month of November to February, while the wet season span from March to October. However, during the dry season, rainfall is sometimes experienced. The average annual rainfall is between 3,000 - 3,500 mm, which is mostly accompanied by lightening, thunderstorm and torrential rain. The average daily temperature is between $26^{O}C$ to $28^{O}C$ (Amukalli *et al*, 2018), with a relative humidity of 70-90% during the wet season and 50% in the dry season.

The soil and geology of the area encourages flooding due to the location of Yenagoa on the lower delta basin plain. The major geological characteristic of the study location is sedimentary alluvium formed by abandoned beach ridges due to many tributaries of the River Niger. The soil texture ranges from medium to fine grains. Soils are mainly loamy at the topsoil and sandy clay loamy at mid depth and bottom soil (Amukalli *et al*, 2018). Yenagoa is a lowland area, which is characterized by flood plains, with the highest elevation of about 15metres above sea level.

The major drainages in Yenagoa are the Nun River, Epie and Ekole creeks, with other smaller creeks that crisscross the area as shown in Figure 1. The vegetation is fresh water swamp forest type which houses one of the largest concentrations of timber, oil palm and numerous forest products and non-fossil products like ceramic clay, sand and gravel. There are also floating vegetation such as water hyacinths along the creeks and rivers. These water hyacinths are good bio accumulators and thus used for bioremediation purposes.

Flooding is the major natural hazard experience in Yenagoa, which is caused by several factors such as: heavy precipitation, height above sea level, soil type, poor urban development control, leading to indiscriminate buildings that block natural drainage channels, poor reclamation of wet lands for development, building on flood plains and indiscriminate waste disposal, which block both natural and the few available man-made drainage channels. Also, the release of water from upland dams, especially from Republic of Cameroon, has also aggravated floods experienced in Yenagoa, especially the 2012 flood, which brought untold hardship, loss of property and lives in the city. This situation has made it imperative to analyze and map flood risk in the city to better understand the situation and provide workable solutions to the flood challenges usually experienced during any flood event in Yenagoa.

Data Collection and Treatment: The quasi-experimental design was adopted in this study, which involves direct field observation and onsite measurements. The direct field observation was employed to examine the general condition of the study area and gather attribute data to further explain locational data obtained in the field through the use of global positioning system (GPS) and measuring tape. The locational data included flood heights and land elevation, while the land use and land cover data were sourced from satellite images downloaded from Google earth and Landsat. In sampling the topographical surface, adaptive random sampling technique was adopted in the study. Triangulated Irregular Network (TIN) was used to select points believe to represent the terrain so as to ensure local changes and characteristic points were included. Data used in this research were captured and mapped as points, lines and polygons. Points in their natural state (undeveloped bare ground) were randomly selected from the various communities in the study area.

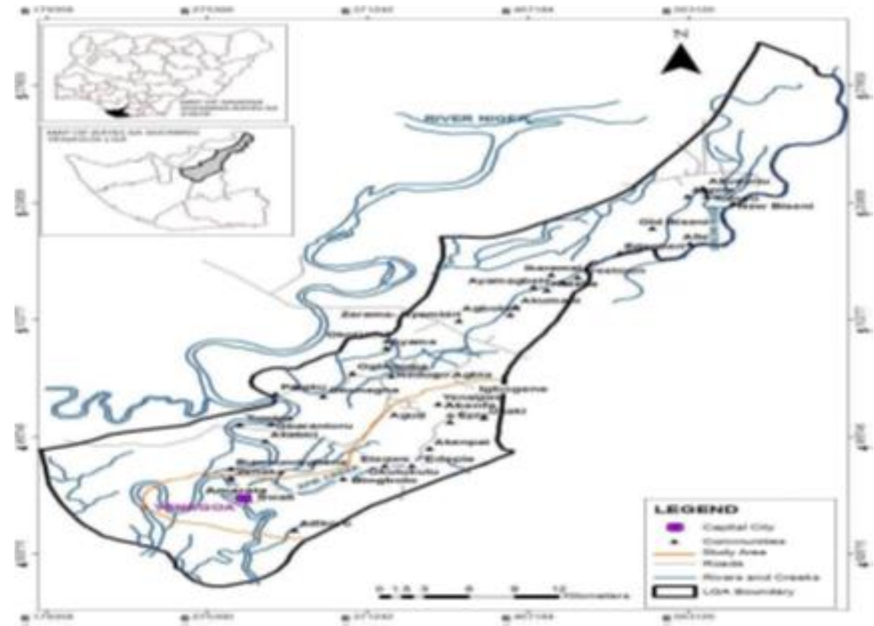

Fig 1: Yenagoa Local Government Area Showing the Study Area
Source: Ohwo (2019)

Satellite imagery for year 2019 was downloaded from the internet (Global land cover facility of Google Earth) as well as maps from Bayelsa State Geographic Information System. Germaine (78s) GPS was used to derive the coordinates (X, Y, Z positions) of locations. Software application such as: ArchMap in the ArcGIS 10.0 was used for contouring and GIS analysis. Microsoft suit - Microsoft Word and Micro Soft Excel were used for word processing and data presentation.

Data Analysis: Descriptive analytical method was adopted in this research. The Geographic Information System (GIS) technology was used in the processing, analysis, interpretation and presentation of remotely sensed information.

In addition, it was used in showing spatial variation of slope, land cover, flood levels and relief information through appropriate maps. Maps were used in presenting statistical risk information for every geographic data. Attributes and geometric characteristics were highlighted and assessed.

The spatial analysis that was adopted for this research includes overlay analysis and geo-statistical analysis. Maps covering different themes in the study area were produced with each map layer representing a single geographic feature. Overlay layer mapping was done to cross one map with another so as to identify risk levels and the predominant land cover in the study area.

RESULTS AND DISCUSSION

Land Elevation and Risk Zones: In this study, location and elevation data showing position and height information in X, Y, Z coordinate system provided unique addressing formats of coordinates which ease the identification of points/places. The ellipsoidal elevation data obtained from the hand held GPS device were harmonized to produce a digital elevation model of shuttle radar topography mission (SRTM) data to produce an elevation map of Yenagoa as shown in Figure 2. Based on the obtained data, Yenagoa was classified into three elevation zones: 3-7m (high risk zone), 7-9m (moderate risk zone) and 9-12m (low risk zone).This shows that all things being equal the lower the elevation of an area the higher the flood risk. For example, places such as Opolo, GRA and Kpansia have lower flood risk compared to Swali and Azikoro, which have lower elevations.

Flood Heights and Risk Zones: A flood height is the height reached by a body of water resulting from the overflow of a river beyond its normal limits. A flood height of the various locations in Yenagoa as presented in Table 1 was generated using a measuring tape. Heights were obtained from marks left by previous floods (2012, 2018, 2019) on buildings and bridges. Points were purposively sampled to get height information which was later used to obtain a mean flood height. The mean flood height of 34.3cm was obtained and was inputted in the GIS software to create 3 zones, which represent high, medium and low risk zones as shown in Figure 3.

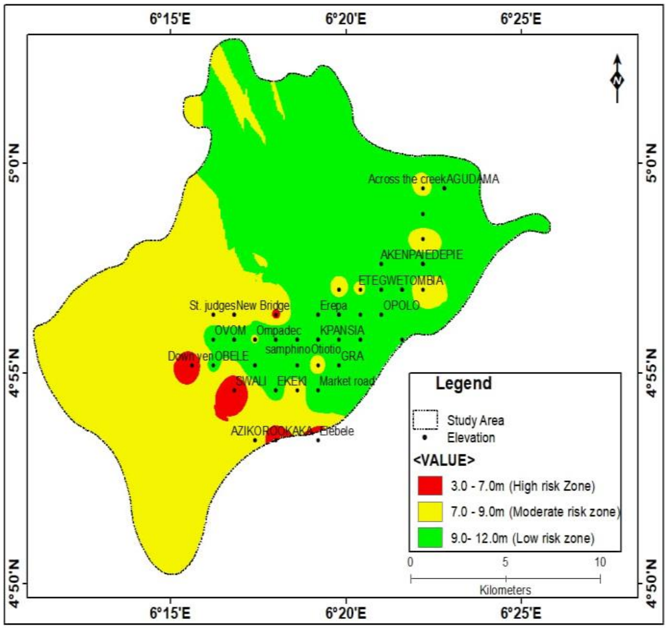

Fig 2: Elevation of Yenagoa
Source: Researchers' fieldwork, 2019

Table 1: Flood Height in Yenagoa, 2019

S/N	Location	Latitude	Longitude	Flood Mark (cm)
1	Agudama	04°59'18.1"	06°22'46"	30.5
2	Akenpai	04°57'40.6"	06°22' 24"	15.2
3	Edepie	04°57'34.2"	06°21'55.9"	10.1
4	Tenacious Street Edepie	04°56'45.8	06°22'04.1"	15.2
5	Etegwe	04°57'17.3"	06°21'27.8"	7.6
6	Tombia	04°57'12.1"	06°21'24.3"	63.5
7	NIIT Road	04°56'19.1"	06°21'03.4"	20.3
8	Opolo	04°56'16.8"	06°20'07.8"	48.3
9	Okutukutu	04°56'53.1"	06°20'54.7"	55.9
10	Biogbolo	04°56'53.1"	06°19'57.2"	10.1
11	Yenezuegene	04°55'47.2"	06°19'32.8"	7.6
12	Otiotio	04°55'47.3"	06°19'19"	12.7
13	GRA Kpansia	04°56'23.8"	06°18'11.9"	33.0
14	Okaka Village	04°55'50.8"	06°18'13.6"	58.4
15	Azikoro	04°53'33.8"	06°17'33.1"	30.5
16	Elebele	04°53'16.9"	06°19'04.0"	45.7
17	Ekeki	04°55'46.7"	06°17'51.4"	10.1
18	Ebis Road Amarata	04° 55'34.9"	06°16'48.2"	7.6
19	Ompadec	04°55'50.9"	06°17'11.0"	71.1
20	Onopa	04° 06'39.6"	06°16'37.6"	58.4
21	Hospital Water Side Ovom	04°56'08.6"	06°15'53.4"	53.3
22	Obele	04°55'29.1"	06°16'04.1"	20.3
23	Down Yenagoa	04°55'29.1"	06°15'32.4"	53.3
24	Oxbow lake, Swalli	04°54'24.5"	06°16'50.1"	83.8

Source: Researchers' fieldwork, 2019

The location with the highest flood height (83.8cm) was recorded at Oxbow lake, Swali; while the lowest flood height (7.6cm) was recorded at Etegwe, Yenezue gene and Ebis Road, Amarata. In order to map the flood risk zones in Yenagoa, the point data were projected and displayed in the ArcGIS software, the points were thereafter interpolated by using the inverse distance weighting (IDW) in the Geo-statistical tool and specifying the extent of the study area for the interpolation process. The resultant raster data was later reclassified using the reclassify tool under spatial analyst tool. The mean flood height data derived from the IDW in the ArcGIS was used to define the various risk zones in the study area. Places with low elevation were assigned the value of 3 (locations above the mean flood height 34.3cm and above), places with moderate elevation were assigned the value of 2 (these are places close to low elevations with likelihood of flood occurrence if flood were to exceed mean flood height) and places with high elevation were assigned the value of 1 (areas below and within mean flood height). These three classes represented the various risk zones in the study area as displayed in Figure 3.

Land Cover Classification: In analyzing land cover in Yenagoa, the Landsat, 2019 imagery downloaded from the internet was processed, using digital image processing (DIP), which involved feeding the raw satellite imagery into the computer and manipulating it to generate new image which contain the required thematic information.

Land cover classification was done to produce various types of land cover which were reclassified based on their surface roughness values. The land cover classes were represented by individual polygons, which show the spatial structure and the layout of land use in Yenagoa.

Table 2 shows the various land cover area extent and percentages. Of the total land area of 27,972.11 hectare, dense vegetation occupies 11,687.43 (41.78%) hectare, being the highest, while the land cover with the lowest area extent was forest with 1,554.79 (5.56%) hectare.

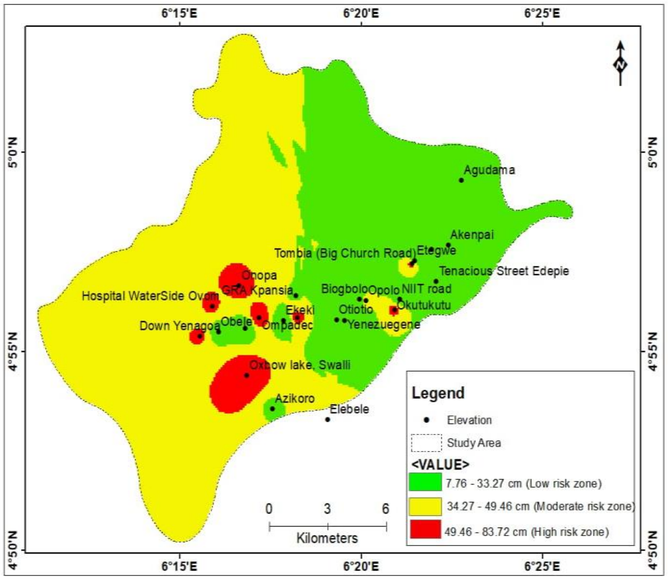

Fig 3: Flood Height and Risk Zones in Yenagoa
Source; Researchers' fieldwork, 2019

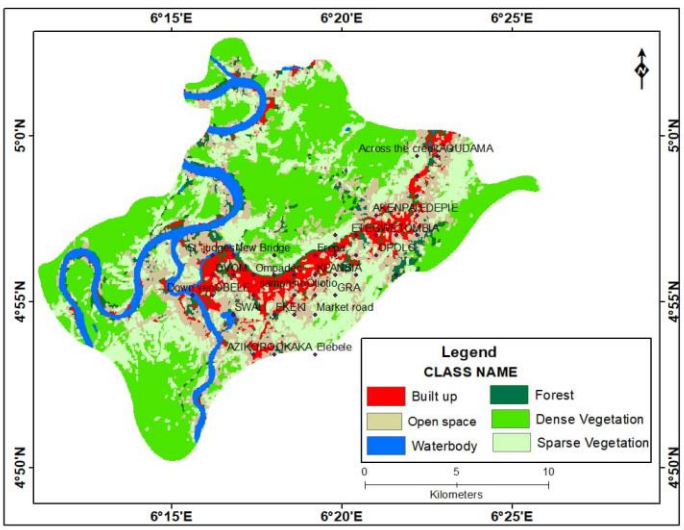

Fig 4: Land Cover Image of Yenagoa City (Landsat, 2019)
Source: Researchers' Laboratory Work, 2019

Table 2: Land Cover/Land Use Classification of Yenagoa

S/N	Class Name	Area (ha)	Percentages (%)
1	Built up area	2405.75	8.60
2	Dense vegetation	11687.43	41.78
3	Forest	1554.79	5.56
4	Open space	5152.7	18.42
5	Sparse vegetation	5452.24	19.49
6	Water body	1719.20	6.15
7	**Total**	**27972.11**	**100**

Source: Researcher's fieldwork, 2019

Figure 4 shows the spatial distribution of different land covers in Yenagoa, such as area under cultivation, forest, urban (built up areas) and water body. Areas under different land cover have different capacity to absorb and temporarily store (rain) water and produce the balance as flood/runoff, while vegetation encourages infiltration and reduces possibilities of flood while built up areas allow for runoff and poor absorption of rainwater thereby leading to accumulation of water and eventual flooding.

Land Cover at Risk of Flooding: In order to determine land cover at risk of flooding, the weighted overlay operation was conducted. The converted reclassified raster dataset now in vector format was overlaid with the already classified land cover map of the study area which was also converted to vector data, the intersection tool under geoprocessing was used to extract areas that have low, moderate or high risk of flooding.The weighted overlay tool in the ArcGIS spatial analyst toolset was used to overlay the reclassified elevation (Figure 2) and the land cover (Figure 4). Scales were given to the various elements at risk of floods; an arbitrary scale of 1 to 10 was used to define the level each land cover allows and also influence flooding. Flood height was given an influence level of 40%, with the level of risk measured on a scale of 1 to 10, On the Interpolated map, 1 represent low flood height area and was given a scale of 1, 2 represent moderate flood heights areas and was given a scale of 5, while 3 represent high flood height areas and was given a scale of 10, this is due to the fact that areas around high flood height are more prone to flood event than areas around low flood heights. Land cover was given an influence of 60%; built up areas was given a scale of 8, sparse vegetation was given a scale of 5, dense vegetation was given a scale of 2, water body was given a scale of 10, open space was given a scale of 9, while forest was given a scale of 1. A flood risk map was generated based on these criteria; while scales were given based on their ability to encourage or resist flooding and reduce risks. The resultant weight overlay of IDW and weighted land covers are presented in Table 3; while the generated flood risk map of Yenagoa is presented in Figure 5.

Table 3: Weight Overlay of IDW and Weighted Land Cover

Level of Risk	Class Name	Area (ha)	Percentage (%)
	Built-up Area		
Low risk	1	1629.26	5.82
Moderate risk	2	686.61	2.45
High risk	3	89.88	0.32
Total		**2405.74**	**8.60**
	Dense Vegetation		
Low risk	1	6252.53	22.35
Moderate risk	2	5421.91	19.38
High risk	3	12.99	0.05
Total		**11687.43**	**41.78**
	Forest		
Low risk	1	795.11	2.84
Moderate risk	2	692.25	2.47
High risk	3	67.43	0.24
Total		1554.79	5.56
	Open space		
Low risk	1	2569.29	9.19
Moderate risk	2	2390.97	8.55
High risk	3	192.44	0.69
Total		**5,152.7**	**18.42**
	Sparse Vegetation		
Low risk	1	2906.07	10.39
Moderate risk	2	2483.91	8.88
High risk	3	62.26	0.22
Total		**5,452.24**	**19.49**
	Water body		
Low risk	1	380.33	1.36
Moderate risk	2	1253.15	4.48
High risk	3	85.72	0.31
Total		**1719.20**	**6.15**

Source: Researchers' fieldwork, 2019

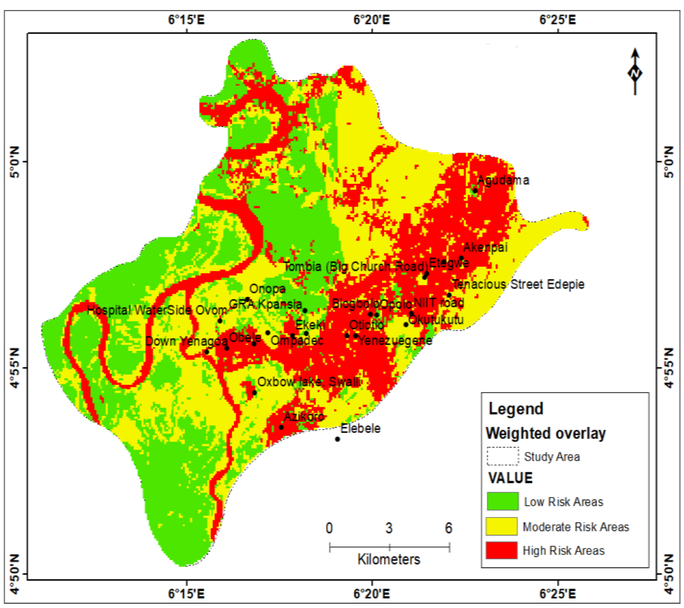

Fig 5: Flood Risk Map of Yenagoa
Source: Researchers' fieldwork, 2019

From Table 3, it is apparent that a large proportion of the area in Yenagoa is susceptible to flooding. For example, 13,439.52 hectares (48.05%) of the total land area of 27,972.11 hectares of Yenagoa is either classified as having moderate or high risk of flooding. Most worrisome is the fact that 776.49 hectares (32.28%) of the 2,405.74 hectares of the built-up area is either moderately or highly susceptible to flooding. Since the impact of floods are more severely felt in built-up areas, inhabitants living in these moderate or high risk areas may suffer high loss of property and socio-economic disruptions to livelihood. This has placed most of the land use/land cover in Yenagoa at great risk at any time floods occur. Having knowledge of these flood risk areas could facilitate tailor-made interventions by relevant government agencies that could significantly ameliorate and mitigate the expected impacts of floods in the affected areas in Yenagoa.

All environmental problems are associated with space and time, that is, risk is a product of hazard, vulnerability or exposure. The absence of any of these items will mean a reduction in the risk level. Geographic information system was used to establish variation of elevation, land cover and flood height. An overlay analysis was carried out to show areas that lie within the various level of flood risk in the study area. The study has established that, most of the built up areas in the study location are under the high risk zone, this is due to poor drainage system and poor development control, which agrees with the submissions of Echendu (2022) that high rainfall, coupled with poor waste management, poor physical planning and poor drainage systems are the major causes of flooding in Nigeria and Ghana.

It was also revealed that the entire study area is at risk of perennial floods, this is in line with the findings of Ologunorisa (2009). However, there is spatial variation in the risk level. The study identified three levels of risk: the high risk zones, which are areas with very poor resistance to flooding, medium risk zones and the low risk zones, which are areas where resistance is high and the potential damage by flooding is minimal.

The entire study area is a flood plain as such a low land area, hence, the difference in elevation is not so evident. However, land elevation drops as one move closer to the southern part of the study area with small variation along the Epie Creek, where the natural dykes have not been significantly altered by development or by natural forces. A good example is across the Epie creek in Agudama, Opolo, and Yenizue Gene areas that have higher elevation and are within areas with low or medium risk zones. Areas with backwash swamps and natural Burroughs that can contain excess flood water or where water is drained into also fall under low and medium flood risk zones especially those areas with low flood heights. Ground truthing and field verification carried out confirmed the various sources of flood risk to include:

(i) Ponding, which is caused by poor drainage facility and blocked drainage.

(ii) Surface runoffs caused by inadequate drainage.

(iii) Seepage by structures in close proximity to wetlands and home foundation below ground level.

The various elements at risk of flooding in the study area include residential buildings, access roads, farmlands, electric power lines, water supply and recreational facilities. From the physical observation, it was evident that flooding affects all of these elements at the various flood risk zones in the study area. Furthermore, it was revealed that residential buildings are the elements that are most at risk of flooding. Some of these buildings are partially or totally submerged during the highest point of the flood season, which was evident in Onopa area opposite St. Jude Girls' Secondary School, and Amarata opposite Imgbi road where houses were totally submerged during the high points of the floods especially in October. Access roads especially those along Alamieseigha drive in Opolo, Captain Ayeni street in Yenizue Epie, Deeper life Road in Okutukutu, and back of Amarata and Azikoro village were most at risk of floods since the roads were built without drainages and some of them are not tarred, which allow for upsurge of groundwater as in the case of back of OMPADEC in Amarata, and Deeper life road in Okutukutu. Some of these roads due to poor engineering works allow for pounding as in the case of Alamiesiegha road in Opolo and Captain Ayeni in Yenezue Epie. The study observed that this result in obstruction of movement, which slows down economic and social activities. When flooding occur sewages and dumps are washed into homes and water bodies polluting the rivers and result in aesthetic deterioration, hence, water supply was another element in the study area that was at risk when flooding occur. This finding is in line with the submissions of Mmon and Ayakpo (2014).

Conclusion: The study has revealed that a large land cover of Yenagoa is at high risk of flooding due to both natural and anthropogenic factors. The high precipitation usually experienced annually, low elevation of the study area and anthropogenic factors have increased the flood risk in Yenagoa. It is therefore recommended that the Ministry of Physical and Urban Development should carryout proper urban development control, which will prevent building on flood plains, wetlands and natural drainage channels. This will reduce the level of hazard when floods occur.

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