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ARTICLE

Floodplain Mapping and Risks Assessment of the Orashi River Using Remote Sensing and GIS in the Niger Delta Region, Nigeria

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ABSTRACT

Residents along the shoreline of the Orashi River have yearly been displaced and recorded loss of lives, farmland, and infrastructures. The Government's approach has been the provision of relief materials to the victims instead of implementing adequate control measures. This research employs Shuttle Radar Topographic Mission and Google Earth imagery in developing a 3D floodplain map using ArcGIS software. The result indicates the drainage system in the study area is dendritic with catchment of 79 subbasins and 76 pour point implying the area is floodplain .Incorporating the 3D slope which reveals that> 8 and <8 makes up 1.15% and 98.85% of the study area respectively confirms the area is a floodplain. Aspect indicate west-facing slope are dark blue, 3D hillshade indicate yellow is very low area and the high area is pink and also the buffer analysis result reveals waterbodies reflecting blue with an estimated area of 1.88 km^2, yellow indicate 0.79 km^2 of the shoreline, red indicate 0.81 km^2 of the minor floodplain and pink contain 0.82 km^2 with the length of 32.82 km. The result from google earth image in 2007 indicate absent of settlement, 2013 indicate minimal settlement and 2020 indicate major settlement in the study area when correlated with 3D Floodplain mapping before and during the flood in other to analyze and manage flooding for further purpose and the majority of the area are under seize with flood like in 2020. Therefore, Remote Sensing and GIS techniques are useful for Floodplain mapping, risk analysis for control measures for better flood management.

1. Introduction

Floodplain mapping is a critical land area that constitutes most landform in the Niger Delta region at large. These areas are majorly used for farming and settlement. The need for development and growth within the Niger Delta has also led to the increase of human settlements on river floodplains and low-lying regions effectively blocking drainage pathways [2]. Geographic Information System (GIS) and Remote sensing have also been applied extensively to flood studies [3] as it reflects all kinds of spatial data in the real world. Three sources of primary sorts of flooding are usually associated with the area such as Coastal, Fluvial, and Pluvial flooding but in this case, our main focus is Fluvial Flooding is caused by overflowing of rainwater from the river to the surrounding environment and filling up smaller streams, rivers, and Lakes [5]. The resultant effect is the breakage of dams, dikes and thereafter making the surrounding environments swampy this type of flood can be classified into two. Overbank and Flash flooding. The degree of fluvial

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flooding is resolute by the quantity of rainfall, the absorption capacity of the soil, and the undulation. [1]. Changes in climatic conditions have led to frequent torrential rainfall heightening the risk of flooding. The high rate of human population growth globally; 1.1% per annum [8], and rural migration has led to the inhabitation of areas predisposed to flooding. By its destructive nature, man is seeking ways to mitigate and where possible, avert these associated hazards, giving rise to the need for floodplain mapping and risk analysis. Therefore, the integration of Remote Sensing and GIS techniques on Floodplain mapping and assessment calls for consigning by applying GIS and remote sensing tools to monitor floods.

2. Study Area

The area under investigation is the lower Orsahi River that falls within Ahoada West LGA in Rivers State in Akinima. The area is a rapidly growing urban area in the South-South geopolitical region of Nigeria. The major communities surrounding it are Biseni and Zarama in Bayelsa State and Jorkarima 1,2,3,4, Akinima, Oruama, Mbiama, Ushie, etc The area is accessible by road and river. This zone is located in longitudes 006^0 20'0" and 006^0 40'0" east of the first meridian and latitudes 04^0 50'0" and 05^0 10'0" north of the equator in the coastal zone of Niger Delta (Figure 1). Its topography is generally low-lying with elevations ranging from below sea level in the south-western flank of the region to about 39 m further inland [2]. The area is drained by tributaries linked to the Orashi River. Various communities in the area are close to hydrocarbon flow stations owned by the SPDC and Agip Oil Company and the Niger delta basin contains a landmass area of about 105,000 km^2 [6]. These structures are facies of the pro-delta Akata Formation. Facies of the Agbada Formation constitutes a paralic delta front. The Benin Formation constitutes a continental delta top facies [7].

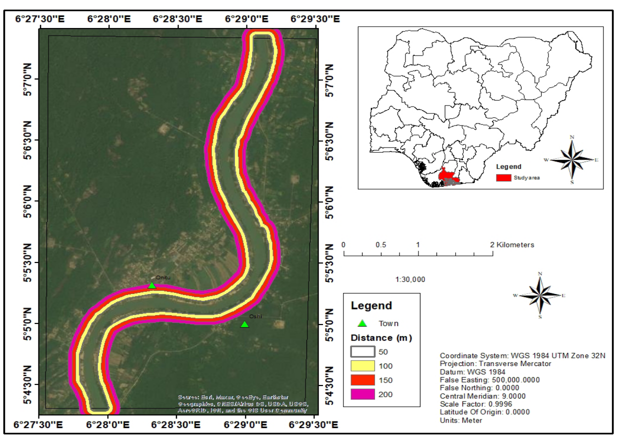

Figure 1. Location map of Orashi River

3. Materials and Method

3.1 Data Acquisition

Shuttle Radar Topography Mission (SRTM) was obtained from United States Geological Survey (USGS) earth explorer [10] while both the High Resolution Google Earth image and the administrative shape file were derived from Google Earth Pro.

3.2 Data Processing

The area of interest was delineated in Google earth, saved as kml file and imported into the ArcGIS software which retains the Projected Coordinate System using WGS UTM Zone N32 which fall within the Niger Delta Region and then converting it to shape file on ArcGIS.

Sub setting of SRTM and Google Earth imagery was done using clipping tools on Arc Toolbox in the following steps: Arc Toolbox → Data Management → Raster → Raster Processing → import Shape file of Area of Interest → import SRTM and Google Earth imagery Create Output Folder → Clip.

3.3 Data Analysis

Multiple Buffer assessment was carried out to outline areas affected by flooding on the floodplain at intervals of 50 m starting from 50 m to 200 m. Spatial Analyst tools were then used to analyze for hydrology and surface, Hydrological tools include Digital Elevation model, Drainage network, Drainage point (pour point), and Catchment. And for Surfaces; Hillshade, Aspect, and slope were evaluated before using the reclassify tool, which is also a spatial analyst tool to classify the digital elevation model into four classes in other to map out floodplain in the region. Furthermore, Arc Scene was used to create a 3D model before the flooding and during the flooding. Incorporating 3D slope and 3D Hillshade, to understand the risk factor of the area such as farming and settlement for floodplain studies. Finally, composite maps were created by overlaying the 3D models with the buffer analysis.

4. Result and Discussion

The understanding of 3D surface in viewing the Earth offers an excellent means of knowing its shape and characteristics, as ridges, peaks or valleys can be seen in greater detail with more information about a place. The following display using a 3D Slope ,3D Hillshade, and Aspect of the surfaces, Drainage network, Drainage point, Catchment, Flood Risk, floodplain mapping and flood mapping during and after the flood including historical google earth image in viewing the risk assessment in 2020.

4.1 The Drainage Network, Drainage Point and Catchment

Since drainage network is the area upon which water-falls and the channel through which it travels to an outlet as seen in Figure 2a. The drainage channel within the study area reveals to be dendritic [4]. The catchment in the study area contains 79 subbasins with a total area of 0.22 km^2 and the total area flowing to a given outlet or pour point is 76 in Figure 2b, indicating the area is a floodplain and that during the rainy season water will flow through the pour point, creating a flash flood.

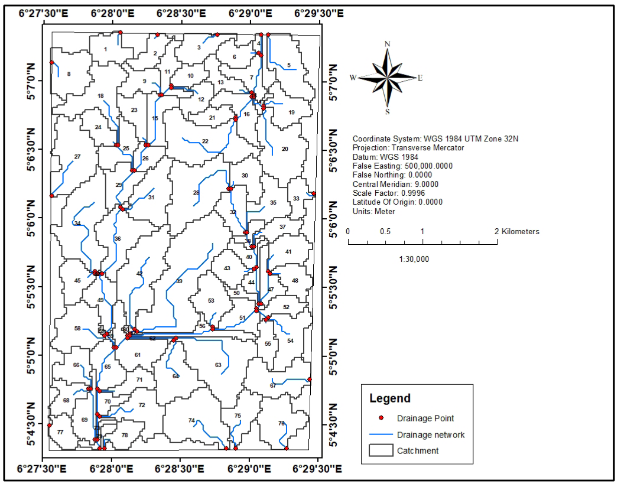

Figure 2a. Drainage network, Drainage point and Catchment Map of the study area

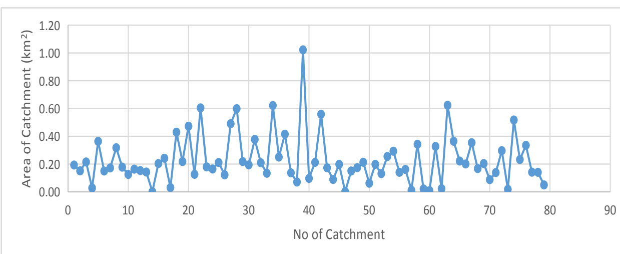

Figure 2b. Chat of area of each catchment against no. of catchment

4.2 The Slope

The following result in Figure 3 shows the slope has darker shades of red indicating steeper slopes with degree greater than 8 has 0.22 km^2 and is the highest in the area in term of slope and the lowest in terms of land area (Table 1) while other ranges from 0 to 2 contain 7.52 km^2 indicate Dark green in the area,2 to 4 has 8.09 km^2 reflecting light green,4 to 6 contain 3.24 km^2 indicate light yellow and 6 to 8 has 0.79 km^2 contain dark yellow and is the second highest slope and second lowest mass land area. In general, the area which slope is >8 contain 1.15% is the high area, and <8 is 98.85% indicating low land area with a low degree of slope.

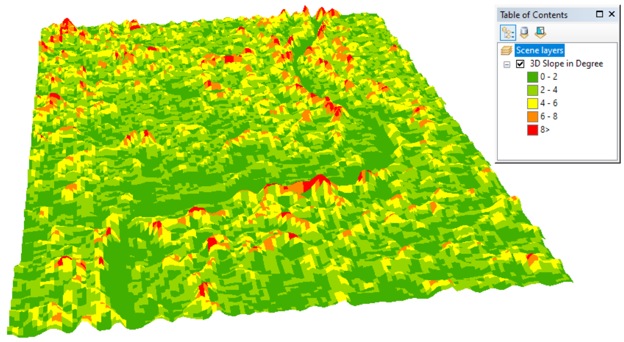

Figure 3. 3D Slope map of the study area

Table 1. Estimated land area of slope in the study area

S/N	Degree (°)	Area (km^2)
1	0-2	7.52
2	2-4	8.09
3	4-6	3.24
4	6-8	0.79
	8>	0.22

4.3 The Aspect

The result in Figure 4 indicates west-facing slopes are dark blue. North facing slope is red and southeast-facing slopes are green etc. with various estimated land area in Table 2. The flat (-1) area in Figure 4 also indicates the Orashi river

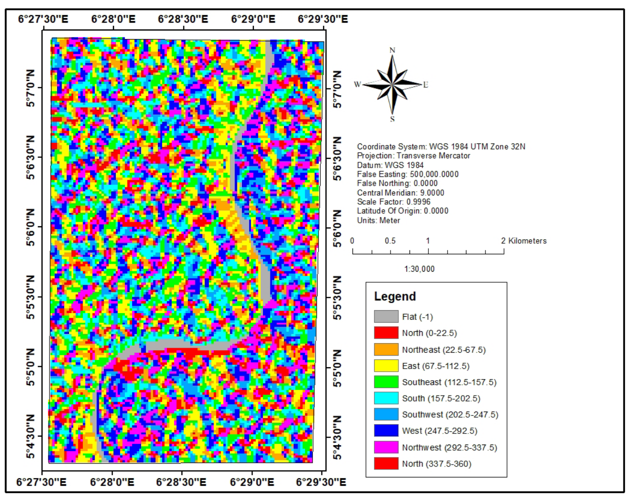

Figure 4. Aspect map of the Study area.

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Table 2. Estimated land area of Aspect in the study area

S/N	Aspect	Area (km^2)
1	Flat(-1)	0.54
2	North (0-22.5)	1.21
3	Northeast (22.5-67.5)	2.06
4	East (67.5-112.5)	2.76
5	Southeast (112.5-157.5)	2.64
6	South (157.5-202.5)	2.33
7	Southeast (202.5-247.5)	2.56
8	West (247.5-292.5)	2.57
9	Northwest (292.5-337.5)	2.44
10	North (337.5-360)	0.95
11		

4.4 The Hillshade

The result in Figure 6 indicates the distribution of light along a surface when illuminated by the light of the sun as defined by a locational bearing expressed in terms of azimuth and vertical angle. Hillshade will increase the perception of depth in a 3D surface for better visualization of the terrain for floodplain mapping and risk analysis of the area i.e. very low area in the terrain are denoted in a yellow, low area in red, and pink for the high areas.

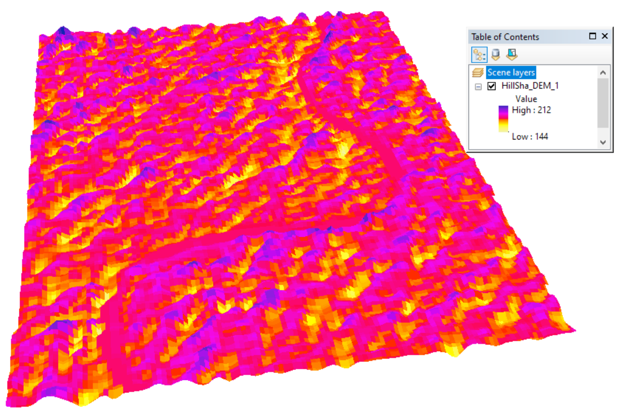

Figure 5. 3D Hillshade map of the Study area

4.5 Buffering Analysis

Buffering analysis used in delineating floodplain area in Orashi River was buffered using multiple buffers with a range of 50 meters to 200 meters away from the river. The result is shown in Figure 6, which reveals that is waterbodies reflecting blue with an estimated area of 1.88 km^2, yellow indicate o.79 km^2 of the shoreline, red indicate 0.81 km^2 of the flood plain, and pink contain 0.82 km^2 with a length of 32.82 km in Table 3

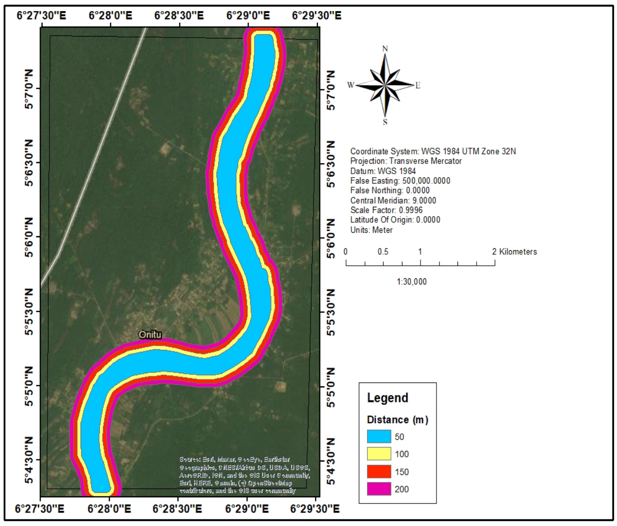

Figure 6. Buffer analysis map of the study area

Table 3. Estimated land area of buffer analysis away from the river in the study area

S/N	Distance Away from river (m)	Area (km^2)	Length (km^2)
1	50	1.88	15.65
2	100	0.79	31.6
3	150	0.81	32.21
4	200	0.82	32.82
Total		4.3	112.28

4.6 Digital Terrain Modeling for Flood Risk Mapping and Terrain Classification

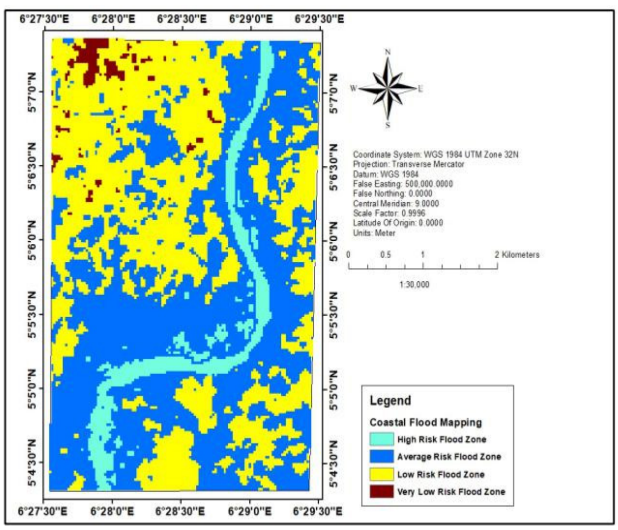

Figure 7a. Flood risk mapping of the study area

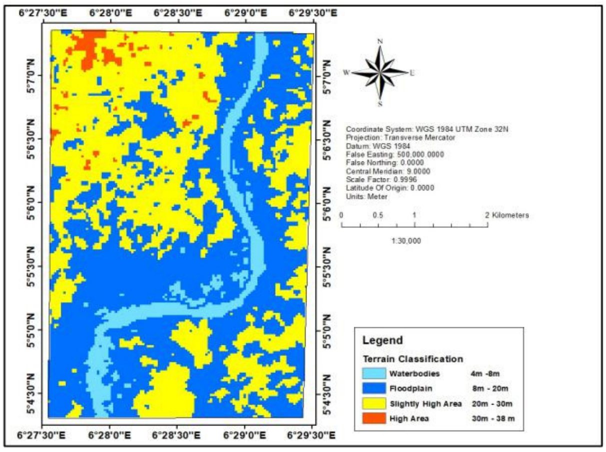

Figure 7b. Terrain classification mapping

Table 4. Estimated land area of flood risk and terrain classification mapping in the study area

S/N	Flood Risk Mapping	Terrain classification mapping	Elevation (m)	Area (km^2)
1	High Risk Flood Zone	Waterbodies	4-8	1.49
2	Average Risk Flood Zone	Floodplain	8-20	9.88
3	Low Risk Flood Zone	Slightly High Area	20-30	8.14
4	Very Low Risk Flood Zone	High Area	30-38	0.35
Total				19.86

From Figure 7a and 7b, it is observed waterbodies indicating high risk flood zone with elevation ranging from 4 m to 8 m with an estimated land area of 1.49 km^2 indicating light blue (Table 4), floodplain contain elevation ranging from 8 m to 20 m indicating average risk flood zone with 9.88 km^2 which constituted the large area, low risk flood zone is map as the slightly high area with 20 m to 30 m indicating yellow with 8.14 km^2 and the high area is map as a very low risk flood zone with elevation ranging from 30 m to 38 m indicate the area is suitable for flood relief center with estimated land area of 0.35 km^2.

4.7 3D Floodplain Mapping and Risks Assessment

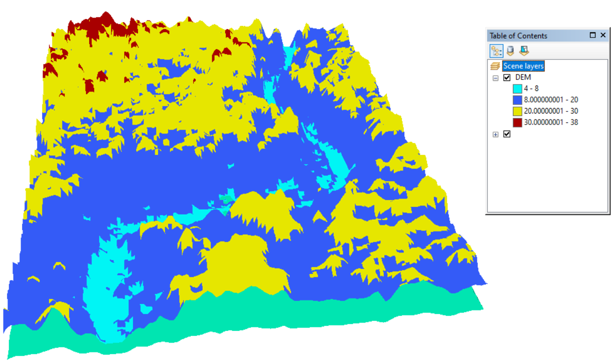

Figure 8a. 3D Floodplain mapping before the flood in 2020

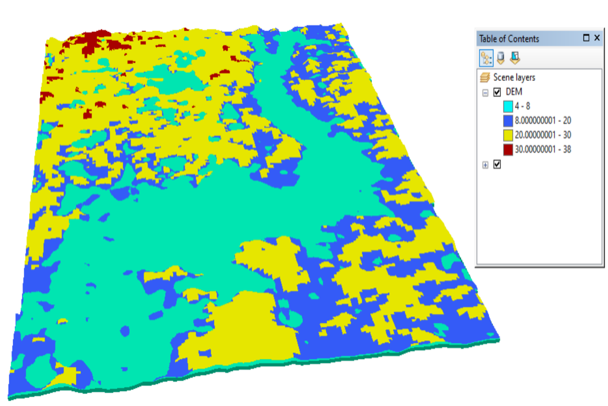

Figure 8b. 3D Floodplain mapping during the flood in 2020

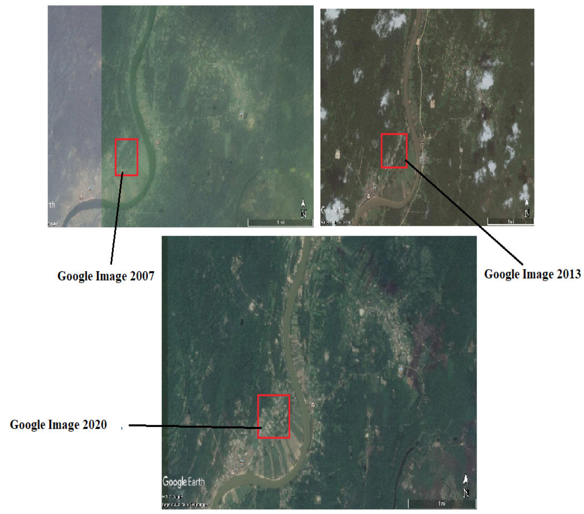

Figure 9. Google Earth historical imagery of 2007, 2013 and 2020

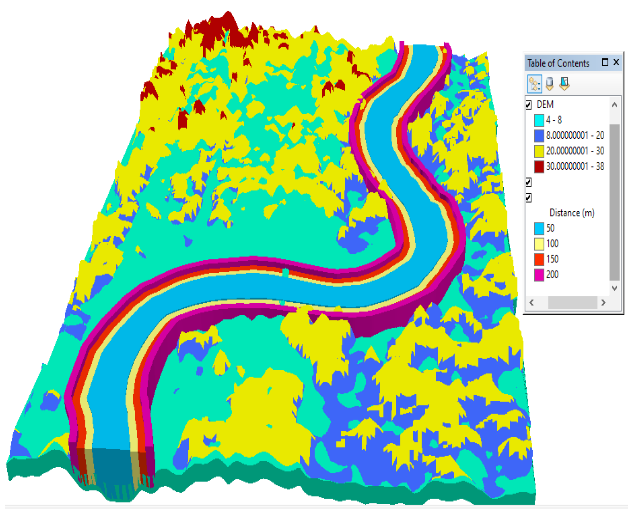

Figure 10. Overlap of buffer analysis on 3D Floodplain mapping during the flood in 2020

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Figure 11. Flood in Akinima Ahaoda West LGA Rivers State [9]

Risk assessment is important in analyzing flooding for proper planning and managing situation to avoid major effect on flooding during flood season in the Niger Delta and other parts of the world in deciding for the building of the structure and site suitability including settlements, farming, road, and railway construction and it is also critical to understand the terrain of the area by carrying out hydrological and surface analysis to investigate the statue of the area, majorly in terms of the drainage system, due to most area in terrain has poor drainage system resulting from lack of planning thereby building structure and road on drainage channels resulting to flooding during the rainy season. From Figure 9 the google earth image in 2007 indicate the absence of settlement in the area, 2013 indicate minimal settlement in the area and 2020 indicate major settlement in the area when correlated with Figure 8a and 8b 3D Floodplain mapping in other to analyze and manage flooding for the further purpose it indicates the majority of the area is under seize with the flood in Figure 8a,8b, also from Figure 10 the overlap of buffer analysis indicate the majority of the area is floodplain from 100 m to 200 m away from the shoreline which can be used for shoreline design for pilling purpose. If the government plan early during 2007 by earmarking on sand filling and piling of the shoreline in the study area they could have minimized the flooding in 2020 and loss of life, properties including farmland resulting in food scarcity in Figure 11. Therefore, the need for government and other agencies to plan and manage for is vital due to flood has come to stay with us but we need to manage our waterways and ensure the people and the government do their part by obeying law and regulation.

5. Conclusions and Recommendation

GIS and remote sensing have proven that using Shuttle Radar Topographic Mission and Google Earth imagery to assess flood risk and map out floodplain is vital for flood management. The result indicates the drainage system in the study area to be dendritic with a catchment of 79 sub-basins and 76 pour points typifying a floodplain. Integrating the 3D slope which highlights that 1.15% of the area is greater than 8^o and 98.85% less than 8^o also confirms the area is a floodplain. Aspect highlights west-facing slope. In the 3D Hillshade yellow very low area and pink, high areas. The buffer analysis result reveals the waterbodies reflected as blue with an estimated area of 1.88 km^2, the shoreline of 0.79 km^2 as yellow, red indicate 0.81 km^2 of the minor flood plain, and pink contain 0.82 km^2 with a length of 32.82 km. Settlement in the area when correlated with 3D Floodplain mapping before and during the flood in other to analyze and manage flooding for further purpose and the majority of the area are under seize with flood like in 2020. Therefore, the need for government and other agencies to plan and manage flooding is vital due to flood has come to stay with us but we need to manage our waterways by ensuring the people and the government do their part by obeying law and regulation.

The State Government should embark on a massive in-depth floodplain mapping for better flood management. Relocation of people inhabiting the floodplain or immediately sand fills the land. Finally, a floodplain can be used for large scale agricultural purposes such as rice farming.

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