An Assessment and Mapping of Coastal Flooding in Niger-Delta; a case study of Bonny, Okrika and Ogu/Bolo of Rivers State

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Research

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Abstract

Background: *This research looks at the assessment and mapping of coastal flooding in Niger-Delta region of Nigeria, staring at the three local governments (Bonny, Okrika, and Ogu/Bolo) in Rivers State that lies at intervals the shores of Atlantic Ocean.*

Result: *At the analysis it was found that most of the study areas lies at the creek and with the steady rise of the sea level, as a result of increase in temperature, most of the study area will have steady occurrence of flooding.*

Conclusion: *Adaptation measures like dike construction, maintenance of natural dune systems, protection of coastal ecosystems, planting of vegetation around the coastal areas and different flood proofing and accommodation activities should be put in place to checkmate flooding in those areas.*

1.0 Background

Since the start of the 20th century, the mean global sea level has been rising. Between 1900 and 2016, the sea level rose by 16–21 cm (6.3–8.3 in). More precise data gathered from satellite radar measurements reveal an accelerating rise of 7.5 cm (3.0 in) from 1993 to 2017, which is a trend of roughly 30 cm (12 in) per century. This acceleration is due mostly to human-caused global warming, which is driving thermal expansion of seawater and the melting of land-based ice sheets and glaciers. Between 1993 and 2018, thermal expansion of the oceans contributed 42% to sea level rise; the melting of temperate glaciers, 21%; Greenland, 15%; and Antarctica 8%. Climate scientists expect the rate to further accelerate during the 21st century. Human activities have modified the environment. Substantial population growth, accelerated socio-economic activities and migration have exaggerated these environmental changes over the last decade. The impacts of these changes on urban climate have become evident in global, regional, and local trends in contemporary atmospheric temperature, humidity, rainfall records and other relevant climatic indicators. For many cities in both the developed and developing nations, urban flooding has been, and continues to be, a major environmental problem. Between 1950 and 2017, the record of flood events registered showed that about 2% occurred in 1950s and increased rapidly to 52.2% by the end of 2017, endangering lives and causing property damage in the process. In the last decade, flood has affected more than 1.4 billion people and accounted for the death of about 100,000 people. Also, between 1998 and 2018, more than 3,136 flood disasters have occurred around the world, with an estimated total damage of US$556 billion

Sea level rises can influence human populations considerably in coastal and island regions. Widespread coastal flooding is expected with several degrees of warming sustained for millennia. Further effects are higher storm-surges and more dangerous tsunamis, displacement of populations, loss and degradation of agricultural land and damage in cities. Natural environments like marine ecosystems are also affected, with fish, birds and plants losing parts of their habitat. Flood is one of the most devastating natural hazards, with a high rate of occurrence affecting many countries worldwide and causing huge economic and great human loss annually (Thilagavathi, et al., 2011; Willby and Keenan, 2012). Floods are the outcome of complex hydrological, geological and geomorphological conditions, deforestation and urbanization, producing substantial social, economic and environmental damages (Mukherjee and Singh, 2019; Skilodimou et al., 2019). Flood occurrence has increased significantly worldwide in the last three decades (Rozalis et al., 2010). Flood disasters are the third most harmful form of geophysical or hydrological disasters when considering the number of deaths recorded (Parker and Canon, 2002; Komolafe et al., 2019) and it is estimated they have generated more than 30% of all disasters globally between 1945 and 1986 (Glickman et al., 1992). A variety of factors influence flood occurrence in cities such as urbanization without corresponding upgrade of drainage infrastructure, limited capacity of river channels, settlements in low areas, and flood plain encroachment are common phenomena attributed to the increasing flood impacts. The manifestation of climate change which is evident in extreme rainfalls has equally contributed to the frequency, severity and intensity of the problem. The effects of sea-level rise such as the coastal processes of inundation and erosion are of great economic and ecological significance considering the intensive and irreversible changes most likely to occur in the coastal ecosystems.

The study areas are Bonny, Okrika and Ogu/Bolo local government of Rivers State. These areas are situated on an island south of Port Harcourt, making them a suburbs of the much larger city and are lay on the coastal area of the Atlantic Ocean, and many times they experiences floods around them. The identification of areas prone to flood can contribute significantly to flood risk management and land use planning such that, potent flood management policies could be put in place, flood defense infrastructure could be constructed and urban development in flood prone areas could be duly monitored.

This study aims to address the impact of flood on the coastal Environment, and is achieved with the following objectives;

- Identify the Land use changes of the study area.
- Investigate and analyze the soil type and vegetation of the area.
- Identify and mapping of potential coastal flood risk areas.
- To create public awareness and enlightenment of the dangers of coastal flooding

3.0 Methodology

The study areas are Bonny, Okrika and Ogu/Bolo local government of Rivers State. These areas are situated on an island south of Port Harcourt. Okrika lays on the coordinate of 4°44'23"N 7°4'58"E and an average elevation of 452 m. While Ogu/Bolo is situated at the coordinate of 4.72°N 7.20°E with a total area of 34sqm. And Bonny located at coordinate of 4°26'N 7°10'E with a total area of 249.27sqm and an average elevation of 450 m. The average annual temperature is between 18 °C to 22 °C with annual range of about 20 °C.

Data Used

The dataset used for this study was secondary data which contains spatial and non-spatial attributes. The dataset includes Landsat 8 Operational Land Imager (OLI) images, topographic maps, temperature and SRTM DEM data. Software packages include; ArcGIS version 10.5, Idrisi.

Table 3.1
Datatypes and sources

Data list	Data type	Data	Data source	Resolution
1. Landsat 8	Secondary	Satellite imagery	Earth explorer	30 m
2. SRTM DEM	Secondary	Satellite imagery	Earth explorer	30 m
3. Digitized Soil Map	secondary	Satellite imagery	Food and Agricultural Organization	

The Landsat data and Space Shuttle Radar Topography Mission (SRTM) was obtained from (URL; http://earthexplorer.usgs.gov). Landsat 8 OLI acquired on 22nd of January 2014 as revealed in Table 3.1, the satellite imagery has 30 m spatial resolutions. SRTM provides a near-global high-resolution digital elevation model (DEM) with great advantages of homogeneous quality and free availability. The Digitized Soil Map of the World, at 1:5.000.000 scale, is in the Geographic projection (Latitude - Longitude) intersected with a template containing water related features (coastlines, lakes, and double-lined rivers). It was acquired from Food and Agricultural Organization.

3.2.1 Software Used
The software used is as listed;

ArcGIS 10.5: The spatial plus statistical analyst extensions of the ArcGIS 10.5 version will be applied to take out both the spatial analyses and the spatial statistical analyses, and also supervised classification was being carried out in Arcgis which was applied to examine the land-use/land-cover between the years of observation.

Microsoft Excel: is a spreadsheet program use to estimate and analyze numerical data. The software was being applied to transmit out the statistical investigation.

To extract the study area, the topographic map covering the Enugu was georeferenced in the ArcGIS environment. The methodology adopted for this work was categorized into four stages (a) Digitized soil mapping (b) DEM classification (c) Land use/ Land cover (LULC). (d) Flood risk mapping.

A. Digitized soil mapping

The creation and the population of a geographically referenced soil database generated at a given resolution by using field and laboratory observation methods coupled with environmental data through quantitative relationship. Digital soil mapping is the prediction of soil classes or properties from point data using a statistical algorithm. Data was collected at fao website and was downloaded in shapefile format, which was analyzed in Arcgis software.

B. DEM classification.

DEM is a digital model that provides topographic information. The classification will be based on Terrestrial and Non Terrestrial data.

C. Land use/land cover:

IDRISI was used for Image Analysis this include:

Pre-processing - operations before the key statistics study and removal of evidence, are referred to as radiometric or geometric corrections.

Image Enhancement - increase the form of imagery to promote graphic understanding and examination. Spatial filtering enhances precise longitudinal configurations in an image.

Image Transformation - mutual processing of statistics from numerous spectral bands. Arithmetic procedures (i.e. deduction, tallying, duplication, partition) are achieved to syndicate and convert the unique bands into "different" images that enhanced presentation or focus assured topographies in the sight. Techniques: Spectral or band rationing and principal components analysis.

Image Sorting and Study – regularly executed on multi-channel statistics groups (A) this procedure consign small pixels in an image to a specific class or subject.

(B) Grounded on arithmetical features of the pixel intensity values. Supervised classification was employed. Classes are bare land, rocks, waterbody, vegetation, and built-up areas.

D. **Flood risk mapping.**

Flood risk maps are the essential tools for land use planning in flood-prone areas. The basic criteria for mapping are usually chosen according to flood return periods. Sometimes, the expected water depth or dynamic considerations are used instead. The process involves the selection of bio-physical and/or socio-economic factors of an area; the combination of the selected factors with the decision maker’s preferences allows a user to create a composite suitability index. This process results into a multi-criteria and multi-parametric decision making problem.

4.0 Data Analysis, Results And Discussion

All the factors contributing the causes of flooding were delineated & examined, drainage, soil types, slope, landuser/land cover, and geomorphology, their results are discussed intensively as follows:

Soil mapping: Soil texture is the "feel" of the soil when a moist quantity is manipulated between thumb and forefinger. It is one of the more useful tests in evaluating soil. Sands because of their large grain size allow faster permeability of water than clays. Sands hold very little water. Loam soils contain sand, silt and clay in such proportions that stickiness and non-adhesiveness is in balance - so the soils are mouldable but not sticky. The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. Loam soil has an infiltration rate of 10–20 mm/hr, while Sandy-loam soil has infiltration rate of 20–30 mm/hr. these are the two soil texture in the study area while the third is creeks alone the river banks.

Digital Elevation Model: The geomorphologic relief and elevation analysis is an important factor and central to this study. The Digital Elevation Model (DEM) used for this work, was 15 m spatial resolution. It was generated from digitized contour with 50 feet interval extracted the SRTM data. Digital Elevation Model and the output revealed relief to varying in height from less than 15.57 m to 89.64 m. From analysis, 15 settlements lies within 15.57–25.58 meters above mean sea level, 5 settlements are within 26.59–46.60 meter above sea level, and 11 settlements are above 47.61–89.64 meters above sea level.

Slope and Elevation: Slope discovers the steepest downhill slope for a position on a surface. The Slope command captures an input surface raster as well as calculates an output raster containing the slope at every cell. The decrease in the slope value, the flatter the terrain, and the increase in the slope value, the steeper the terrain the output slope raster may be calculated as percentage slope or degree of slope. Flooding occurs due to slope failure, a stable slope is one whose resisting forces are more than the downslope driving forces, Flood occurs when gravity and other driving forces exceed the strength of slope materials (rocks and soil) in slope, majority of the slides happen in the category Moderate, Moderately Steep and steep. High slopes are often associated with low vulnerability while low slopes have an increased level of flood vulnerability. Slope length and steepness influence the movement/velocity and speed of water down the slope of the settlement are measured in percentage Unit: (%) < 0–2.0, 2.0–3.4, 3.4–5.1, 5.1–7.4, and 7.4–8.6.

Flow Direction

The factor in deriving hydrologic characteristics of a surface is the ability to establish the trend of flow from each cell in the raster. This is done with the Flow Direction tool. This tool captures a surface in the form of input and outputs raster showing the trend of flow in every cell. If the Output drop raster option is selected, an output raster is formed showing a ratio of the highest alteration in elevation from every cell along with the trend of flow to the path length amid centers of cells which is shown in percentages. If the Force the entire edge cells to flow outward option is selected, the entire cells along the edge of the surface raster will flow outward from the surface raster. Figure 4.4 is the flow direction grid model of the research area created using DEM. The flow direction map shows variations in the slope of the research area, with values ranging from 1-128 indicated with shades of colors from blue to yellow. The blue color region shows areas of very low elevation while the blue is the area of fairly high altitude.

Land use/land cover: Each composed image was ordered into 4 classes: built-up areas, vegetation, Roads, and water body. The outcome of the classifications of land cover is found in Fig. 4.5. The classification and quantification of images of the study zone (which covers an aggregate of land area of 759.46 square kilometres (km^2) were necessary for the detection of changes in various LULC observed within the study area and over the study period. Thus, the fixed LULC dispersal for the study year was in 2014. The table reveals that, Vegetation occupies the largest area with 355.74 $km^2$of the entire study area, while built-up covered 275.94 km^2, water body covered 125.47 km^2 and roads occupied the least area of 2.31 km^2.

Flood risk mapping: In 2007 the Intergovernmental Panel on Climate Change (IPCC) projected a high end estimate of 60 cm (2 ft) through 2099, but their 2014 report raised the high-end estimate to about 90 cm (3 ft). A number of later studies have concluded that a global sea level rise of 200 to 270 cm (6.6 to 8.9 ft) this century is "physically plausible". A conservative estimate of the long-term projections is that each Celsius degree of temperature rise triggers a sea level rise of approximately 2.3 meters. Elevation of raster is essentially the grid of cells, each cell containing an elevation above mean sea level, so we want to know what will be flooded, so if we assume that the sea level will rise by 15ft in future for a variety of reason like increase in temperature, more than 50% of some of the parts of Okrika will experience frequent flooding in years to come. While less than 50% of parts of Bonny and Ogu/Bolo will experience flooding in years to come.

5.0 Adaptation And Conclusion

Coastal flooding is a sudden and abrupt inundation of a coastal environment caused by a short-term increase in water level due to a storm surge and extreme tides. The magnitude and extension depend on the coastal topography, storm surge conditions and broader bathymetry of the coastal area. Flooding constitutes a particular challenge in low-lying areas as deltas and coastal plains and land subsidence caused by sediment deficits or ground water extraction can further exacerbate the problem. Technical measures for flood control include dike construction, maintenance of natural dune systems, protection of coastal ecosystems, planting of vegetation around the coastal areas and different flood proofing and accommodation activities. Generally, even moderate flooding hazards should be taken very seriously due to the potential disastrous consequences, and flood protection is a key aspect in coastal Disaster Risk Reduction. This will help to improve in the management of these challenges in a holistic fashion.

The study presented the flood estimate mapping of Bonny, Okrika, and Ogu/Bolo of Rivers State whereby several villages are severely flooded leaving people homeless, destroyed properties, agricultural lands, posing a health risk to the inhabitants. The combination of spatial data sets and multi-criteria analysis with geospatial application software to arrive at results such as land-use landcover map, soil type map, and flood mapping. This makes the methodology used in this study very flexible to be utilized in any region provided that specified local factors are taken into account. From the geospatial analysis, the result revealed that Okrika has the higher tendencies of flooding impacts, while Bonny and Ogu/Bolo also get flooded but not as Okrika. This spatial analytical capacity utilized in this study will not only mitigate the consequences of flooding, rather it can be utilized as a decision support system for planning, preparedness, prevention, mitigation, response, recovery for the possible occasion of flood activities in the study area.

Abbreviations

Cm
Centimeter
DEM
Digital Elevation Model
Ft
Feet
IPCC
Intergovernmental Panel on Climate Change
Km^2
Square Kilometres
LULC
Land Use / Land Cover
NDVI
Normalized Differential Vegetation Index
OLI
Operational Land Imager
SRTM
Space Shuttle Radar Topography Mission

Declarations

Ethics approval and consent to participate:

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Consent for publication:

Not applicable

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Not applicable

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Not applicable

Authors' contributions:

Various works involving the analysis and fieldwork were done by the main and co authors in this research.

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Figures

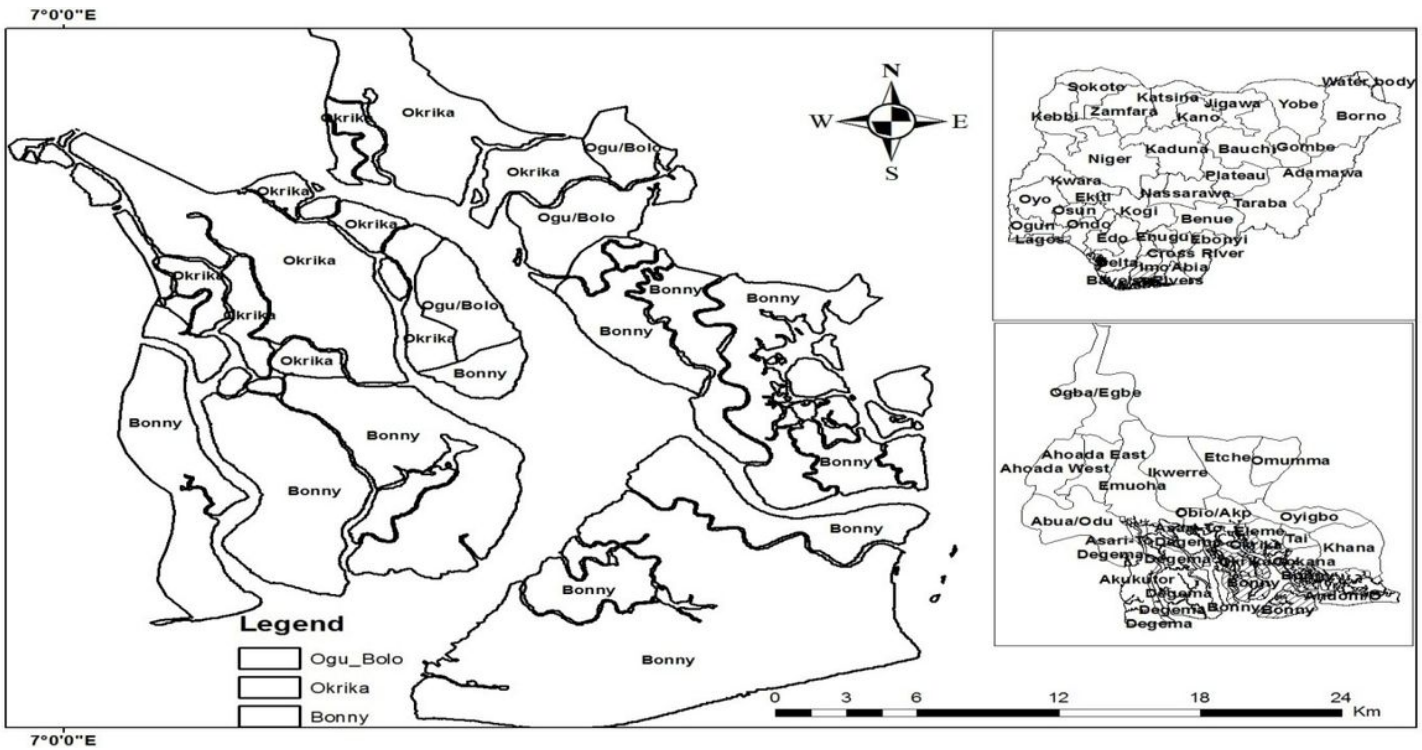

Figure 1

Study area Map

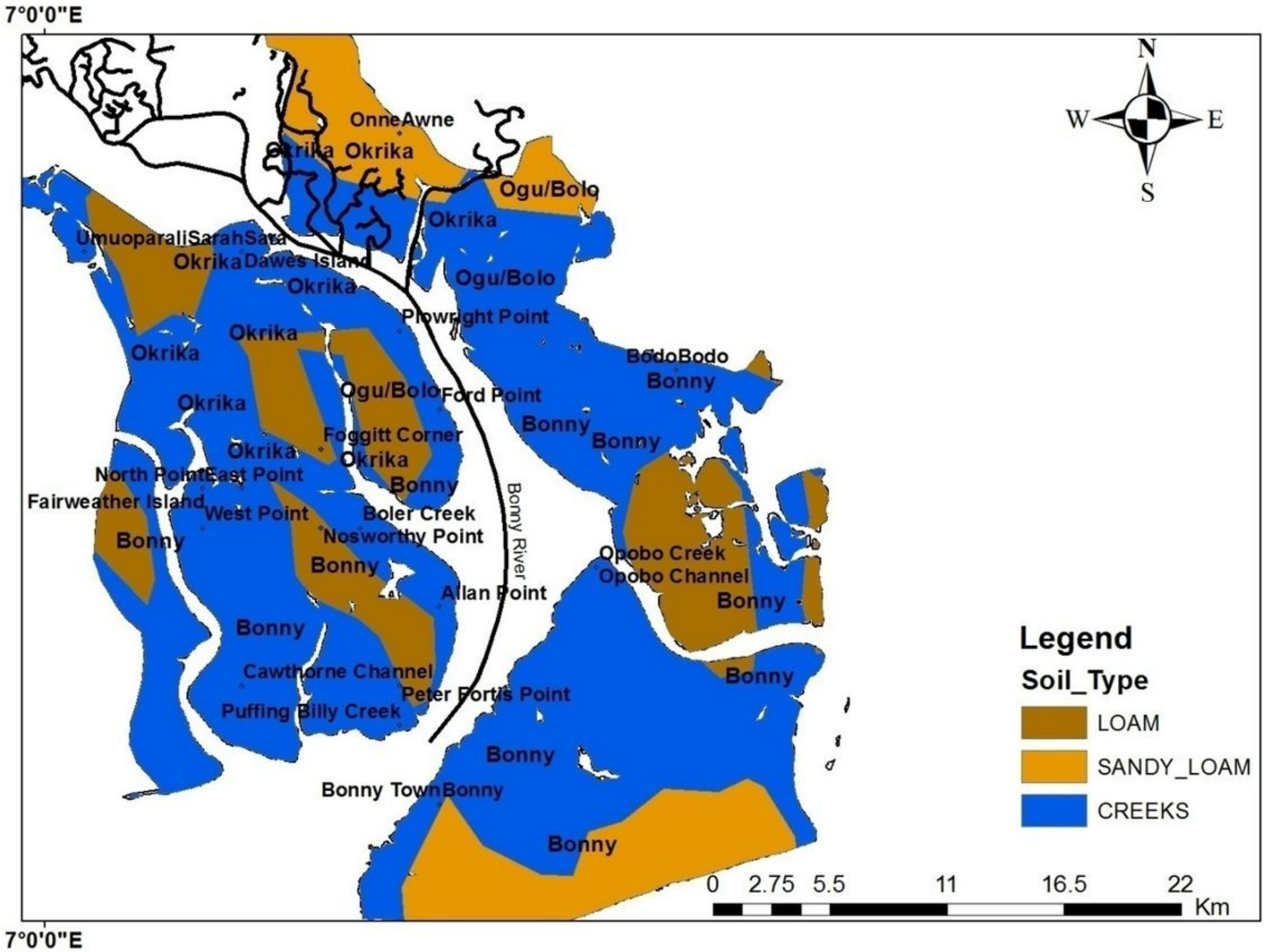

Figure 2

Soil Mapping of the study area

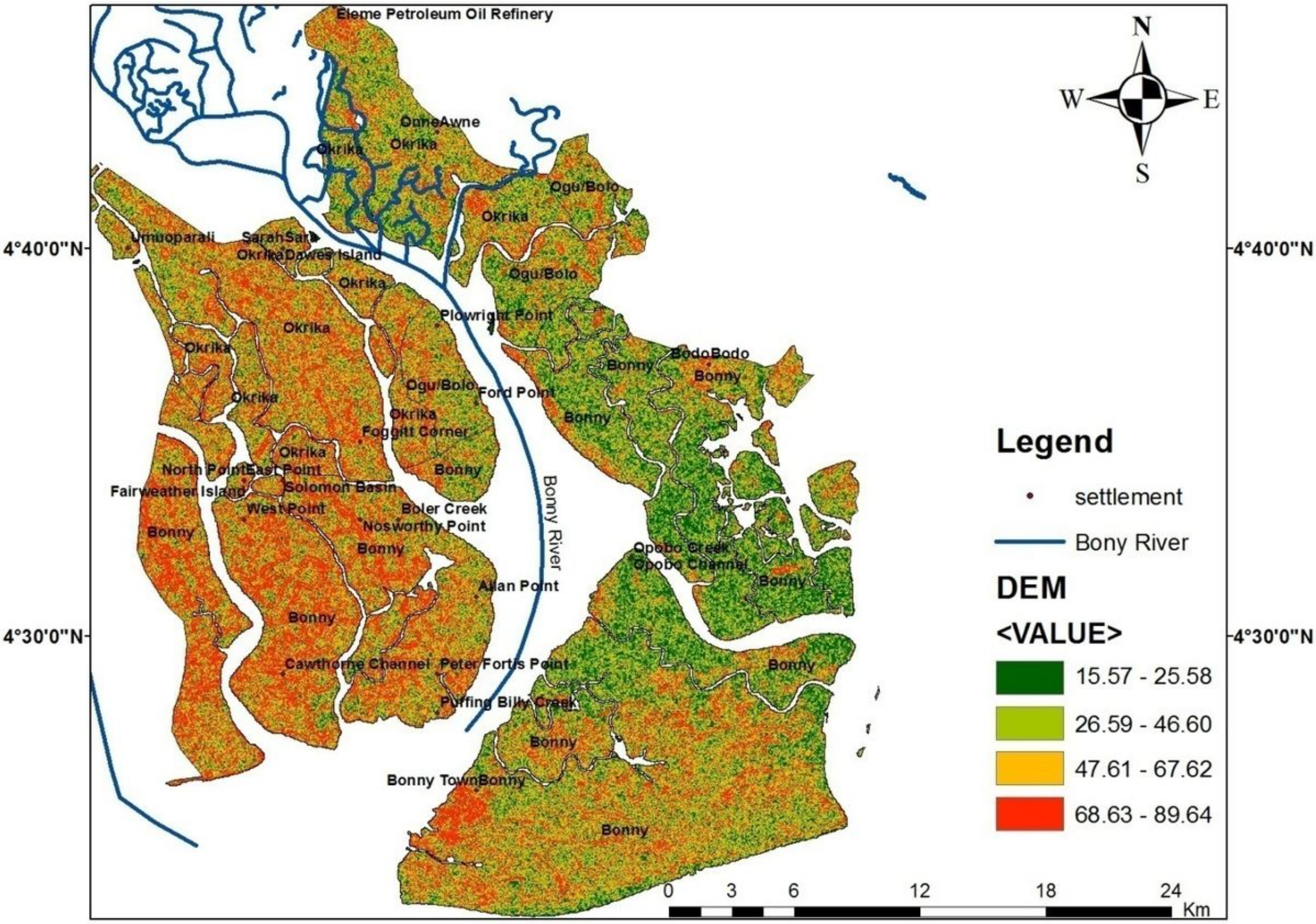

Figure 3

Study area map showing DEM

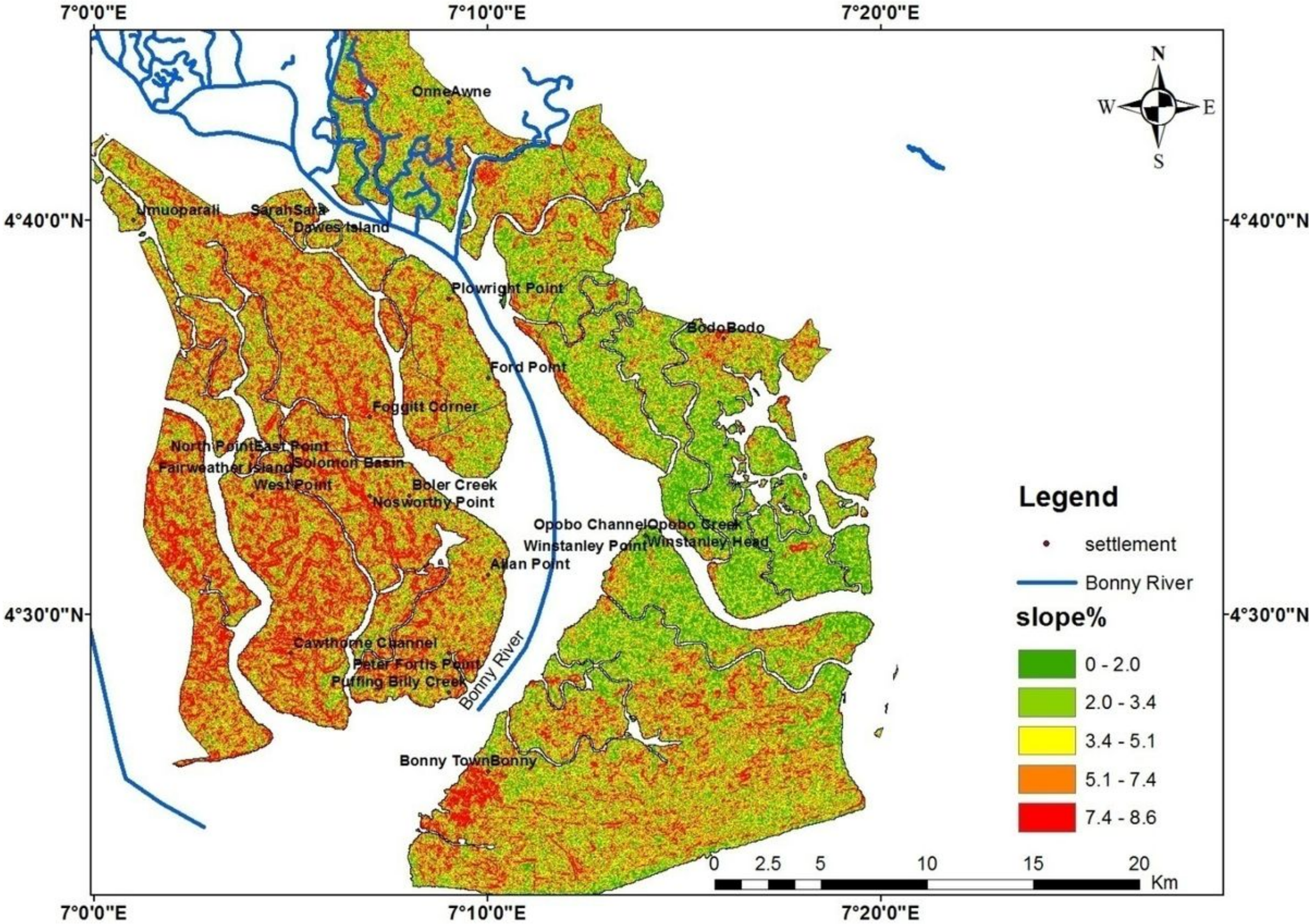

Figure 4

Study Area Map showing Slope (%)

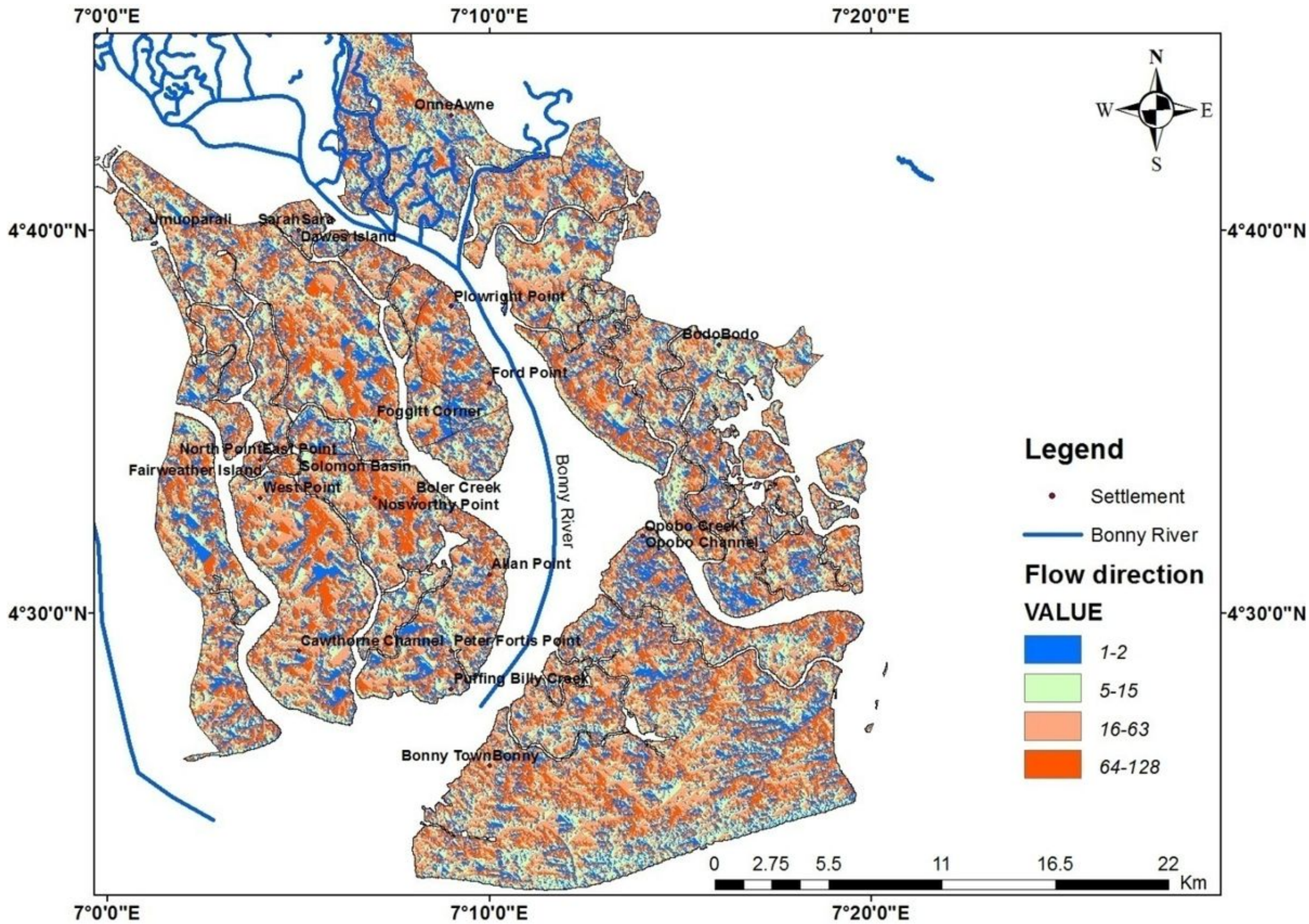

Figure 5

Study Area Map showing Flow Direction

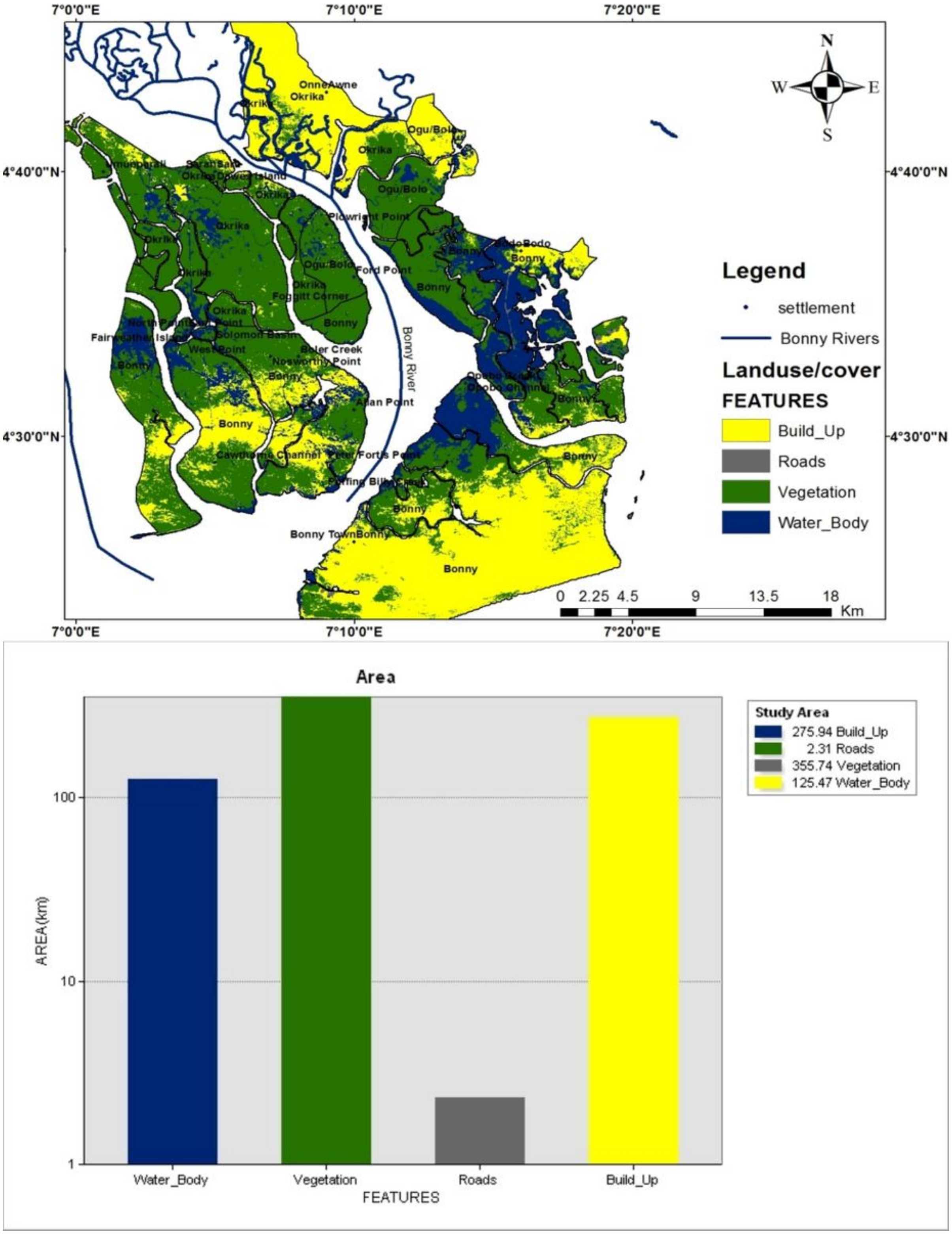

Figure 6

Study Area Map Land use/cover

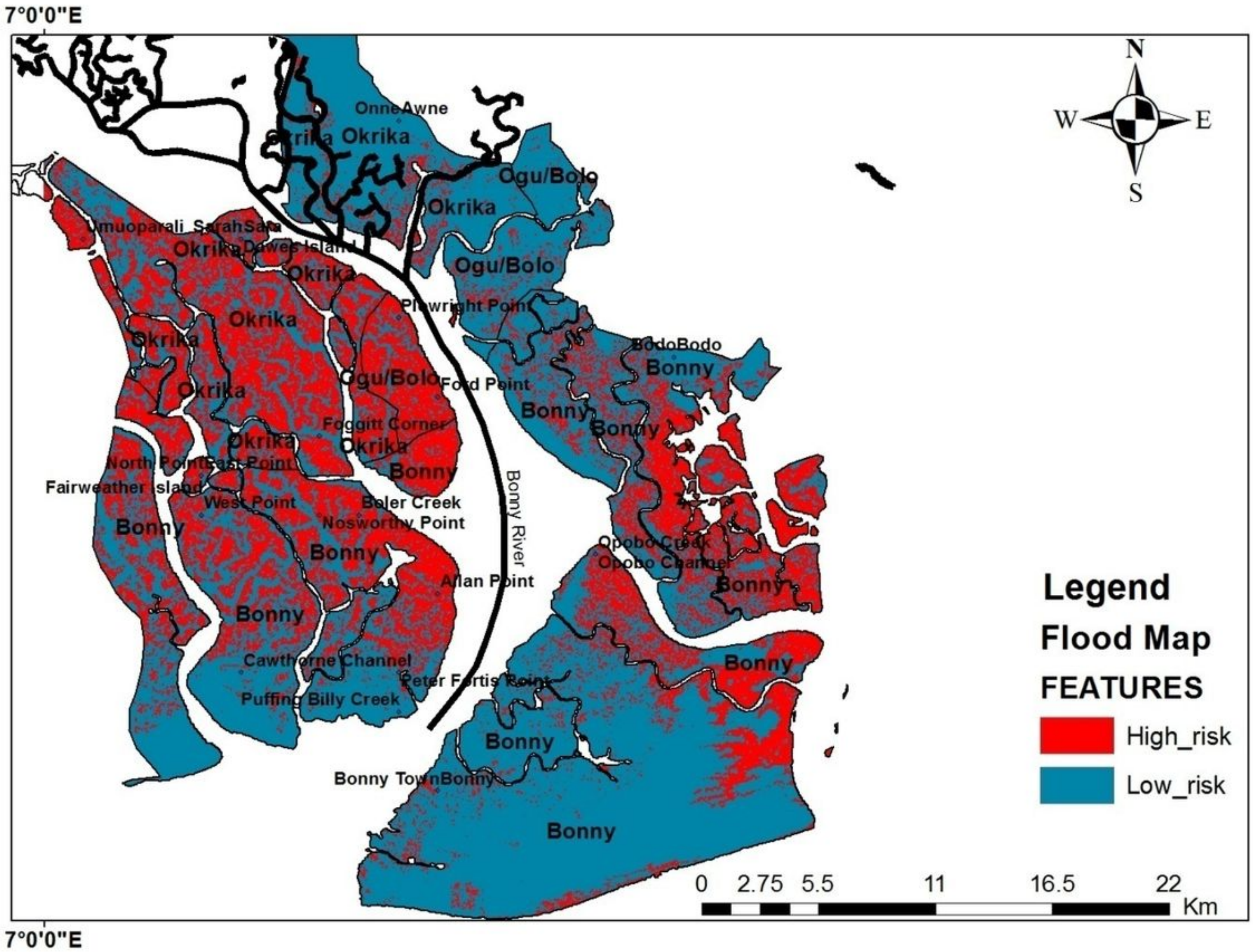

Figure 7

Study Area Map showing Flood risk mapping