

# **Spatial Analysis of Flood Vulnerability Levels in Port Harcourt Metropolis Using Geographic Information Systems (GIS)**

By

\*Eludoyin O.S. and Weli V.

Department of Geography and Environmental Management, University of Port Harcourt, Port Harcourt, Nigeria.

\*Corresponding Author's E-mail Address: [tundeeludoyin@gmail.com](mailto:tundeeludoyin@gmail.com)

## **Abstract**

The study identifies spatial variations in flood vulnerability levels in Port Harcourt metropolis with the use of geographic information systems (GIS). This study considered four factors and these included landuse types, drainage, residential densities and elevation. The elevation data and drainage data were derived from the topographical map of scale 1:35000 while the land use types were derived from the imagery of Port Harcourt metropolis downloaded from Google Earth, 2010 version. Both the topographical map and imagery were geo-referenced to geographic coordinates and geographic features were digitized in form of shapefiles using both Arcview GIS 3.3 and Arc GIS 9.2 versions. Analytical Hierarchical Process (AHP) was adopted in this study whereby many flood factors are ranked and overlaid for decision making. The contour data was used to generate the digital elevation model (DEM) through the process called kriging in ArcGIS 9.2. Based on the ranking index, factors considered were reclassified to three levels of vulnerability namely highly vulnerable, moderately vulnerable and lowly vulnerable through ranking method and these reclassified factors were then overlaid using an addition operator. The analysis shows that communities like Eagle Island, Ojimbo, Kidney Island were highly vulnerable to flood while communities like Choba, Ogbogoro, Rumualogu were moderately vulnerable. Communities like Rumuigbo, Rumuodomaya, etc were lowly vulnerable to flood. The highly vulnerable places covered 98.18 square kilometres, moderately vulnerable was 220.46 square kilometres and lowly vulnerable areas covered 330.77 square kilometres.

Keywords: Flood monitoring, GIS, ArcGIS 9.2, Arc View 3.3, Kriging, Interpolation, Vulnerability

## **Introduction**

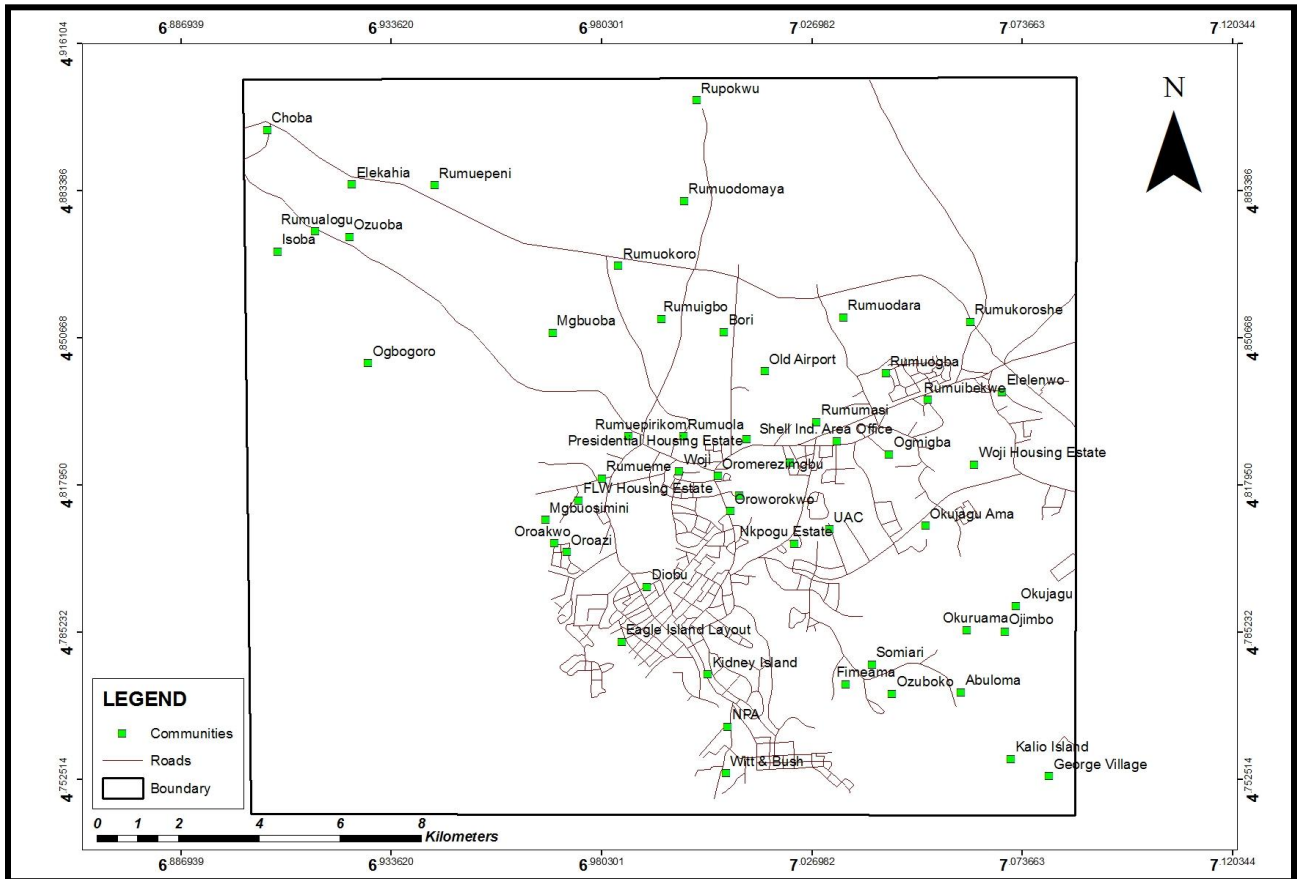
Floods are natural disasters that have been affecting human lives since time immemorial. Floods are associated with some extreme natural events that happen on a drainage basin, river channels, catchment, or watershed. Floods disrupt the social systems and cause enormous economic losses as well as loss of human lives and destruction on our high way (Akpokodje, 2010). According to DMSG (2001) cited in Irimescu et al (2010), floods are among the most devastating natural hazards in the world, widely distributed leading to significant economic and social damages than any other natural phenomenon. Although, flood hazard is natural, human modification and alteration of nature's right of way can accentuate the problem, while the disastrous consequences are dependent on the degree of human activities and occupancy in vulnerable areas. In urban watershed, physical developments of diverse ramification can create flood situations in areas hitherto not considered prone to flood (Akintola, 1978). In a related development, Stancalie et al (2006) suggested that the flood risk arises because the human use river flood plains which conflicts with their natural function of conveyance of water and sediment and that in the assessment and analysis of flood risk it is important to remember that risk is entirely a human issue. Flood is no doubt one of the major environmental problems affecting the livelihood of an area especially an urban area in which Port Harcourt metropolis is not in exemption meaning that Port Harcourt is a typical flood prone area. Therefore, monitoring of the flood system in the areas vulnerable to flood and also to provide flood vulnerability map in the metropolis has become very vital to the socio-economic development of the region and in doing this, Geographic Information System (GIS) is believed to be very important in generating such maps through rigorous spatial analysis. Burroughs (1987) viewed GIS as a tool for storing, manipulating and displaying large quantities of geographic information in a micro computer. He stressed further that the geographic data which is stored describes objects from the real world in terms of their position on the earth with respect to a known coordinate system, their attributes which are unrelated to their positions and their spatial interrelations with objects around them. GIS has the ability to quickly manipulate, analyze, display geographic data and also retrieve the existing data and compare if necessary in order to predict what is likely to happen in the future (Miller, 1997). GIS is any system that captures, stores, analyze, manages, and present data that are linked to location. In Port Harcourt, extensive studies on flood like (Ologunorisa 2001, 2004, and 2009);

had been carried out using conventional methods but the application of GIS in monitoring flooding seems to be deficient. This study therefore examines GIS as a useful and important technique to monitor flood in Port Harcourt metropolis. The proper monitoring and forecasting of flood will help in the proper allocation of the urban land use and to a greater extent give warnings to the flood prone areas in the metropolis which help to reduce the havoc or lost caused by flood.

### **Study Area**

The study area is Port Harcourt metropolis. It lies on latitudes  $04^{\circ} 47'$  and  $04^{\circ} 54'$  North and longitudes  $06^{\circ} 54'$  and  $07^{\circ} 40''$  East and enjoys a tropical monsoon climate with lengthy and heavy rainy seasons from April to October ranging from 2000mm to 2500 mm and very short dry seasons. The temperature is high all the year round and a relatively constant high humidity. The study area is influenced by urbanization or urban sprawl whereby smaller communities have merged together and form megacity. The reason is due to high influx of people resulting to rapid growth of the population size in the study area due to the expansion of oil industries. The soil is usually sandy or sandy loam underlain by a layer of impervious pan and is always leached due to the heavy rainfall experienced in this area. The study area is well drained with both fresh and salt water. The salt water is caused by the intrusion of sea water inland, thereby making the water slightly salty. The relief is generally lowland. The vegetation found in this area includes raffia palms, thick mangrove forest and light rain forest.

**Figure 1: Map of the Study Area**



**Sources: Rivers State Ministry of Lands and Housing and Google Earth, 2010**

## Methodology

### Sources of data

The primary data used for this study were obtained from four sources. The data includes topographical map of scale 1:35000 obtained from the Rivers State Ministry of Lands and Housing, Port Harcourt and satellite imagery of the study area obtained from Google Earth, 2010 Version. Contour, communities and drainage were derived from the topographical map and land use map was derived from the imagery. The topographical map of scale 1:35000 was scanned and imported to Arcview GIS 3.3 version whereby it was geo-referenced to geographic coordinate and thereafter the contour lines were digitized. The imagery was also geo-referenced and the landuse types were captured and labelled into built up areas, water body, derived forest,

and farmland. From the contour map, point data having the X, Y and Z coordinates were generated. The X (Eastings) and Y (Northings) coordinates were generated from script avenue (an extension program in Arcview GIS) while the Z (Height) values were the contour values. All the shapefiles (i.e. contour, point data, land use, drainage) were imported to ArcGIS 9.2 environment whereby further analyses were performed. The point data were used to generate digital elevation model (DEM) through interpolation method called Kriging. This shows the varying elevations of the Port Harcourt metropolis. This study considered DEM (elevation), residential densities, landuse types and drainage as the parameters used to generate flood vulnerability mapping in the study area because the study employs the use Analytical Hierarchical Process (AHP). AHP is a multi-criteria decision making technique, which provides a systematic approach for assessing and integrating the impacts of various factors, involving several levels of dependent or independent, qualitative as well as quantitative information (Bapalu and Sinha, 2006). It is a methodology to systematically evaluate, often conflicting, qualitative criteria (Saaty, 1980 cited in Bapalu and Sinha, 2006)). AHP is like other multi-attribute decision models which attempt to resolve conflicts and analyze judgments through a process of determining the relative importance of a set of activities or criteria by pairwise comparison of these criteria on a 9-point scale (Bapalu and Sinha, 2006). AHP is often used to compare the relative preferences of a small number of alternatives concerning an overall goal. AHP is now popular in decision-making studies where many factors are considered (Bapalu and Sinha, 2006). Therefore, each of the parameters was reclassified into three which included highly vulnerable, moderately vulnerable and lowly vulnerable through the ranking process or weight rating. Flood vulnerability map (FVM) was later generated through by overlaying the reclassified maps of all the parameters using addition operator to generate the vulnerability or flood risk map of Port Harcourt metropolis (i.e.  $FVM = \Sigma \{Reclassified (Elevation, Distance to Drainage, Residential Density, Land use types)\}$ ).

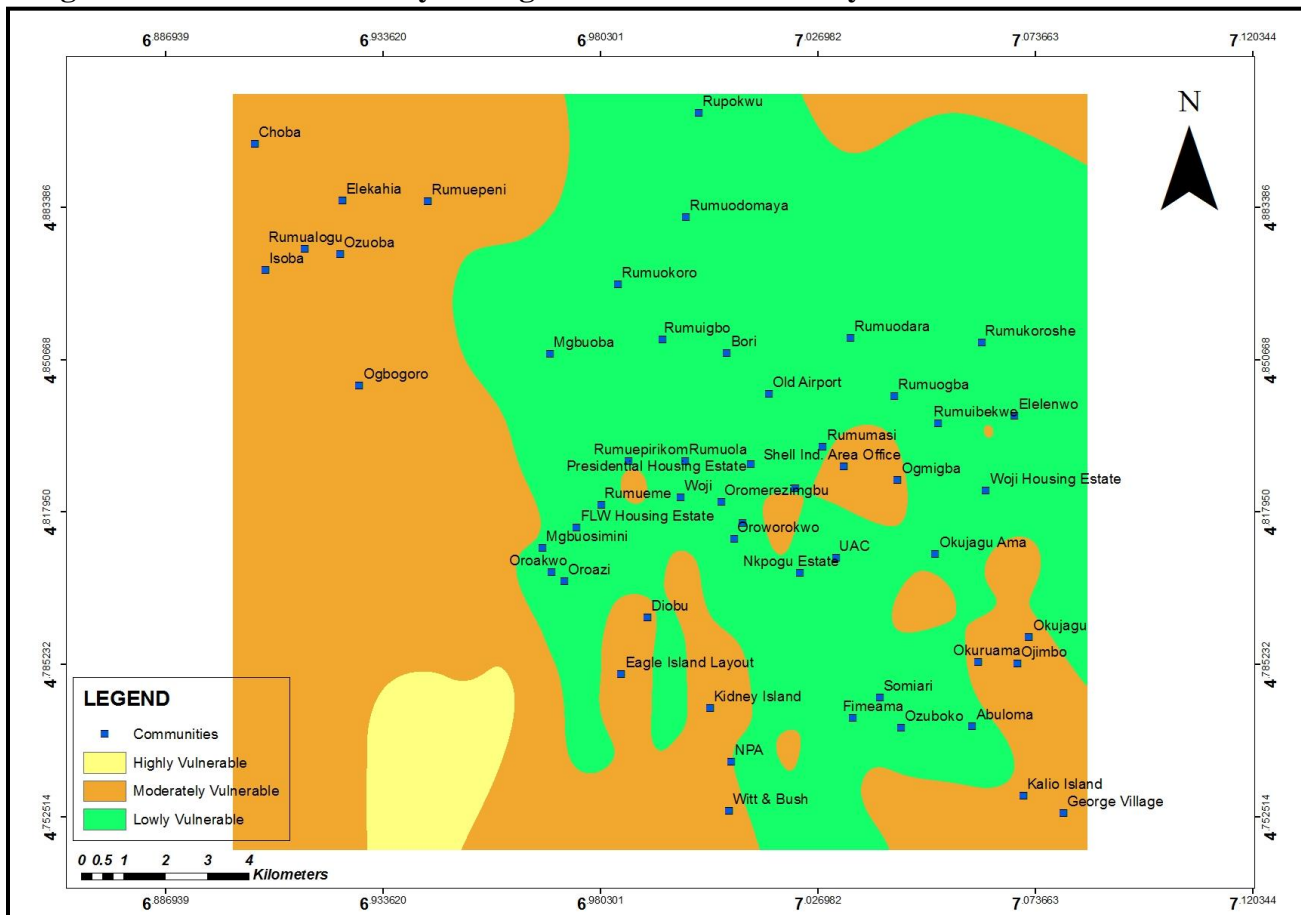
## **Results and Discussion**

### **Reclassification based on Digital Elevation Model of Port Harcourt Metropolis**

The DEM or surface analysis of Port Harcourt metropolis reveals that the relief fall within the range of 0 and 70m. Communities like Choba, Elekahia, Rumualogu are on elevation of 50m

while places like Rumuodara and Rupokwu are 70m. Some areas like Kidney Island and Eagle Island are between 20 and 40m. This shows that different communities are located under different elevation. The whole study area was reclassified to different vulnerability capacities based on the elevation map. The area between 0 and 10m was classified as highly vulnerable, areas between 11 and 50m are moderately vulnerable while areas above 50m are classified as lowly vulnerable areas. Figure 3 below therefore explains that the whole area was delineated into three vulnerability levels. The map shows that communities like Choba, Elekahia, Ojimba, Kalio Island etc are moderately vulnerable while like communities like Rupokwu, Rumuodara, Rumuigbo, Elelenwo etc are lowly vulnerable. However, very small area which is not far from Eagle Island is highly vulnerable.

**Figure 2: Flood Vulnerability through Elevation in the Study Area**



Source: Author's Analysis, 2010.

### **Reclassification based on Residential Densities of the Study Area**

This is the total population of resident occupying a particular communities at a given time and space. While some areas are highly populated, some are thinly populated and this in effect has some contribution to the generation of flood anywhere (Shrestha, 2004). The vulnerability levels have direct relationship with the population which proves that areas of high population may have high residential densities. Based on this, communities are highly, moderately and lowly vulnerable. Highly vulnerable areas include Rumuokoro, Diobu, Eledenwo, Rumuodara Abuloma Rumueme. Moderately vulnerable areas include Ogbogoro, NPA, Witt and lowly vulnerable areas include George Village, Nkpogu Estate, Kalio Island, Rumuepeni, Elekahia e.t.c

### **Reclassification based on Landuse Types of the Study Area**

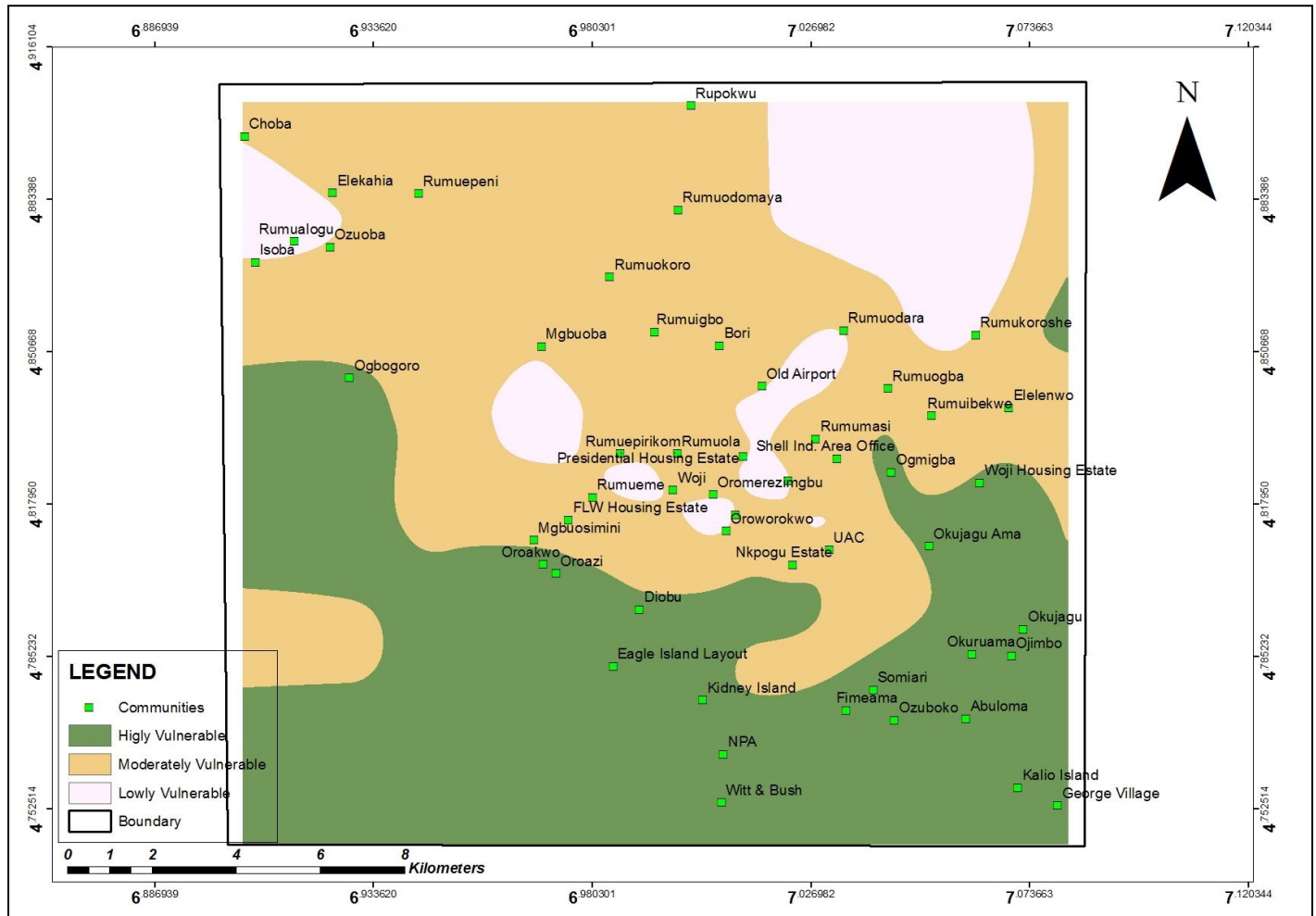
The landuse map reveals that there were about nine landuse types in the study area and these are built up area, cleared land, derived forest, farmland, flood plain, forest, mangrove, swamp forest and water body. Built up area took about one-third of the entire study area. The landuse was later reclassified into three based on the capacity of each landuse type to infiltrate water. It is discovered that built up areas, swamp forest, mangrove, flood plain and water body will highly support flood generation while farmlands and cleared land are moderately; and forest will be lowly. With reclassification analysis on the landuse map, two-thirds of the entire area are highly vulnerable to flood while very small area is lowly vulnerable to flood.

### **Reclassification based on the Drainage of the Study Area (RD)**

The communities were rated based on their distance to the water body in the study area and this helps this to classify the whole study area to three namely; highly vulnerable, moderately vulnerable and lowly vulnerable. The highly vulnerable areas are areas that is 0-200meters from the water body while places between 100 and 500metres as moderately vulnerable while areas greater than 500meters from the water body are classified as lowly vulnerable areas. As a result of this, communities like NPA, Witt & Bush, Diobu, Eagle Island Oroazi, etc fall into highly vulnerable area while communities like Choba, Rumuokoro, Bori, Rumuogba etc, are moderately vulnerable to flood and places like Oroworokwo, Old Airport, Rumualogu etc are lowly

vulnerable to flood. The map shows that majority of the study area is both highly and moderately vulnerable to flood while the spatial extent that is lowly vulnerable is very small.

**Figure 3: Flood Vulnerability through drainage network in the Study Area**

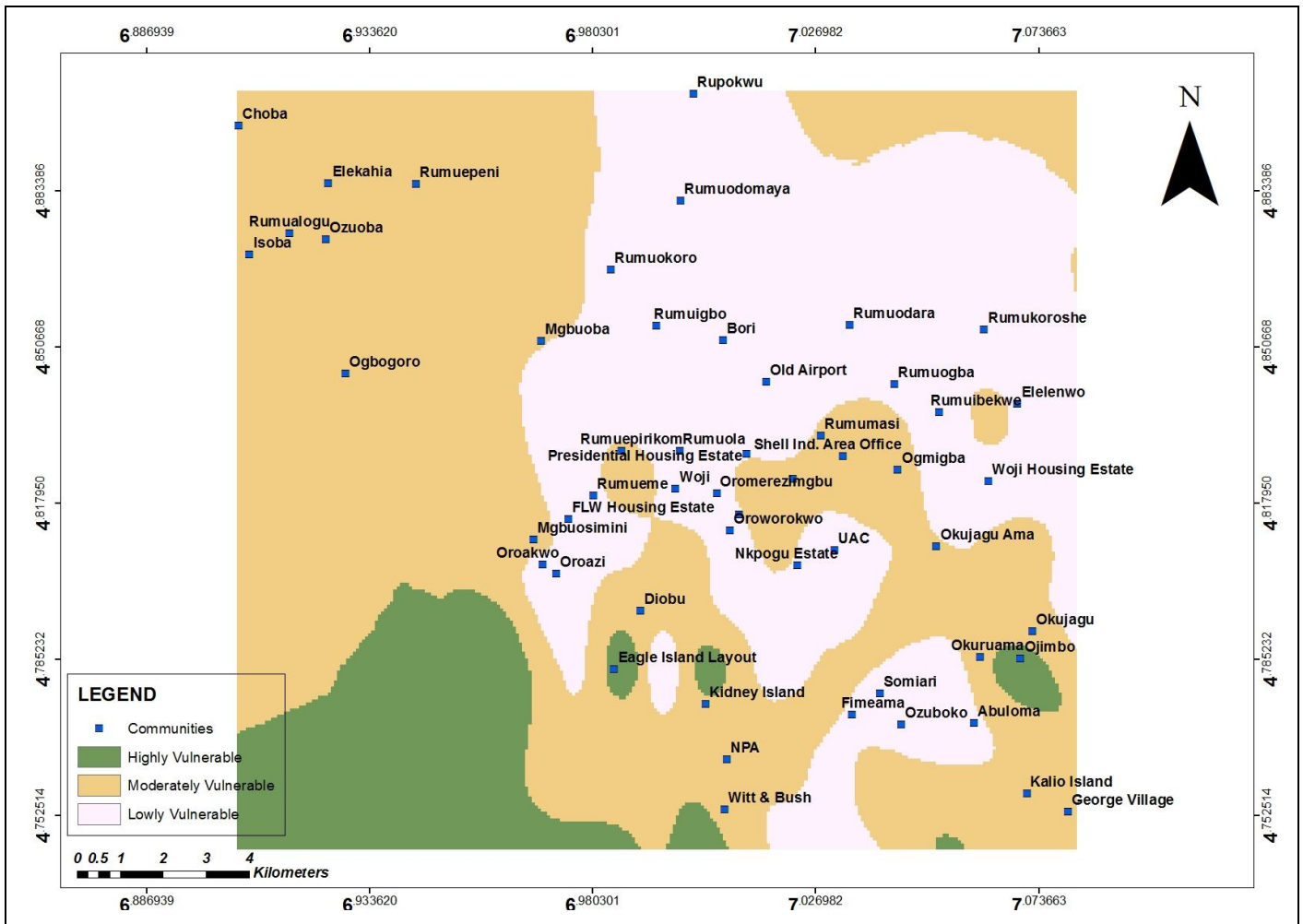


Source: Author's Analysis, 2010.

### Flood Vulnerability Mapping (FVM) for Port Harcourt Metropolis

This study employs overlaying operation whereby all the reclassified drainage, landuse, DEM and residential density using addition operator. The analysis shows that communities like Eagle Island, Ojimbo, Kidney Island were highly vulnerable to flood while communities like Choba, NPA, Ogbogoro, Rumualogu were moderately vulnerable. Communities like Rumuigbo, Rumuodomaya, Woji Housing Estates etc were lowly vulnerable to flood (Figure 4).

**Figure 4: Flood Vulnerability Map for Port Harcourt Metropolis**



**Source: Author’s Analysis, 2010.**

Quantitatively, the flood vulnerability map shows that the highly vulnerable places covered 98.18 square kilometres while moderately vulnerable was 220.46 square kilometres. The lowly vulnerable areas covered 330.77 square kilometers. The analysis therefore reveals that the total area in square kilometres for vulnerability of flood in Port Harcourt was 318.64 square kilometers.

**Conclusion and Recommendations**

This study has demonstrated the use of AHP technique with GIS-based overlay analysis to determine spatial flood vulnerability levels in Port Harcourt Metropolis whereby different attributes or factors have been used. The study reveals that due to closeness to rivers, pattern of

land use, low relief, and residential densities; some areas in the study area were found to be highly vulnerable to flood and these areas included Eagle Island, Kidney Island and while communities like Choba, NPA, Ogbogoro, Rumualogu were moderately vulnerable. Communities like Rumuigbo, Rumuodomaya, Woji Housing Estates etc were lowly vulnerable to flood in such areas. It can be concluded that GIS has revealed the level of flood vulnerability levels in Port Harcourt Metropolis. It is therefore recommended that flood monitoring and management should be encouraged and funded by government and non-governmental agencies. In addition, there is need for high resolution digital elevation data and imageries, microwave remote sensing during a flood which can help to assess damage and support post-disaster management.

### **Acknowledgement**

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