

Investigation of Flood Vulnerability in Parts of Rivers State using Remote Sensing and GIS

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Abstract - The reoccurring flooding in some parts of Rivers State had been a major research concern. Seasonally, coastal communities in the State are flooded to the extent that damages are caused to human lives and properties, especially during heavy falls. In 2018 some communities along the Orashi region were seriously affected by flooding. As recorded by Vanguard Newspapers dated 19th October, 2018, about 9,250 people were displaced, properties worth millions of Naira were destroyed, and farmlands spanning hundreds of hectares were submerged and left impoverished after two days of heavy down pour. Indeed, it was described as very disastrous. This study aimed at performing an investigation on flood vulnerability in some parts of Rivers State using Remote Sensing and GIS. Its objectives are to delineate different vulnerability levels of flooding in the study area, to determine the effect or impact of flooding on different land cover types and to produce flood vulnerability map of the study area. The methodology involves data acquisition, data processing and reclassification and overlay analysis. The classification achieved an overall Accuracy of 85.99% and kappa statistics of 0.8992. The image classification results indicate that vegetation accounted for the largest land cover/use of about 37.23 % with an area of 4096 km² while built up area had the second largest with 31.48 % and an area of 3463 km², water body had 11.51 % with an area of 1267 km², open space had 9.78 % with an area of 1076 km² and mangrove had 9.98 % with an area of 1098 km². The flood vulnerability mapping results also indicated that high-vulnerability zone occupied 28.60% of the entire study area, covering an area of 3147km², while moderate vulnerability zone occupied 27.28%, covering an area of 3001km². Low vulnerability zone occupied 27.05%, covering 2976km² while no vulnerability zone occupied 17.05% covering an area of 1876km². The researcher recommends that the vulnerability maps produced in this research be used in encouraging vulnerability zone residents to prepare for the occurrence of flooding.

Key Words: Flooding, Vulnerability, Land use, Land Cover, Remote Sensing, & GIS



1. INTRODUCTION

Flooding is considered as one of the most devastating events in many parts of the world. In terms of its frequency and distribution river flooding remains as a frequent disaster that has to be faced by civilization in flood plain.

The global flood risk has been increasing as the world's population is rapidly growing. The consequences of rapid population growth are the increasing demand for settlement, food resources, etc.

Ceylon (2004), defines flood as a natural event that has far reaching effects on people and the environment. It is the overflowing of a great body of water over land as a result of flow from heavy

rainfall and other sources such as river overflow due to the volume of water within a water body exceeding the total capacity of the water body.

Abam (2006) defines flood as a large volume of water which arrives at and occupy the stream channel and its flood plain in a time too short to prevent damage to economic activities, infrastructure and homes. Flooding can also occur as a result of failure of man-made water containment system such as dams, reservoirs and pumping systems. Floods are considered one of the hazards making the most impact on human beings (Blaikie et al; ward, 1978).

Smith (2001), also stated that floods claims 20,000 lives and adversely affects around 75 million People worldwide annually, excess water in and of

itself may not be a problem, rather the impacts of floods are felt when it interacts with natural and human made environments in a negative sense causing loss of lives or injury, property, damage, social and economic disruption. Floods are also caused by anthropogenic activities and by human interventions in natural processes, such as urbanization, population growth, uncontrolled and uncoordinated development of the suburb, flood plains, swamps and natural drainage channels, leading to alterations in the natural drainages, deforestation and climate change (Balabanova and vassite, 2010; Kwale and Kondon, 2008; European commission, 2007).

Many African cities have experienced extreme flooding in recent years. Prominent examples are floods due to heavy rain and cyclone that hit Mozambique in February and March 2000 and it led to the worst flood in 50 years in that Country and brought widespread devastation to the capital city, Maputo. Floods and mudslide forced Tens of Thousands to leave their homes in Rwanda, Kenya, Burundi, Tanzania and Uganda. Rwanda suffered the heaviest toll, with more than 50 people dead in 10 days (Action Aid, 2006). The overflowing Dechatu River hit Dire Dawa town at night drowning 129 people and wiping out 220 homes (Demessie, 2007).

Flood is the most common environmental hazard in Nigeria (Etuonovbe, 2011). Flood is not a recent phenomenon in the country, and its destructive tendencies are sometime enormous. Nigeria recorded its first flood in Ibadan, the Oyo State capital in 1948. Since then, the menace has spread like a wild fire to other states of the federation. Reports have it that serious flood disasters have occurred in Ibadan (1985, 1987, 1990 and 2011), Oshogbo (1992, 1996 and 2000), Yobe (2000), Akure (1996, 2000, 2002, 2004 and 2006), Kano (2006), Taraba (2005) and the coastal cities of Lagos, Port Harcourt, Calabar, Uyo and Warri among others have severally experienced many incidences that have claimed many lives and properties worth Million of Naira (Adeoye et al, 2009). The 2012 notable flooding in Nigeria, Urban areas are more exposed to flooding.

Flooding has become a perennial event. Flooding in urban areas is not just related to heavy rainfall, it is also related to change in built up areas (land

use), (Etuonovbe, 2011). Urbanization aggravates flooding by restricting where water can go as a result of the changes in land cover, where large parts of urban environment is covered with roofs, road, and pavements thereby obstructing section of the natural channel (Action aid, 2006).

Seasonally, coastal communities in Rivers State are flooded to the extent that damages are caused to human lives and other properties, whenever it rained heavily. In 2018 for example, certain portion of the settlements in Port Harcourt and bonny was flooded after torrential rains (or intense rainfall). As recorded by Vanguard Newspapers dated 19th October, 2018, about 9,250 people were displaced, properties worth millions of Naira were destroyed, and farmlands spanning hundreds of hectares were submerged and left impoverished after two days of heavy down pour. Indeed, it was described as very disastrous.

Flooding is a common occurrence in many parts of Rivers State especially Port Harcourt. It mostly occurs during the rainy season or at tidal. Rapid rate of land use and population growth over the years now has led to uncontrolled and uncoordinated development of the suburbs, swamps, flood plain and natural drainage channels thereby aggravating the risk of flood hazard in the area. Flood hazards are bound to increase in the future with increasing land use, therefore the need to demarcate flood prone areas for effective flood mitigation is imperative.



Figure 1.1: 2018 Devastating flooding in some parts of Rivers State

Reduction of the risk of flooding will depend largely on the amount of information on the flood that is available and the knowledge of the areas that are likely to be affected during a flood event. Therefore, it is necessary to uses modern day

technique in developing measures that will help relevant authorities and relief agencies in the identification of flood vulnerability (risk) areas and in planning against flooding event in the future.

In the consequent, this research exploited integrated use of Remote Sensing and GIS as a valuable tool in identifying and monitoring flood vulnerability zones in Rivers State. This was achieved by delineating different vulnerability levels of flooding in the study area, and determining the effect or impact of flooding on different land cover types to produce flood vulnerability map of the study area.

2. CONCEPTUAL ISSUES

2.1 Theory of Flooding

A flood is defined by the Oxford English Dictionary as an overflowing or irruption of a great body of water over land in a built-up area not usually submerged. Floods are natural phenomena, but they become a cause for serious concern when they exceed the coping capacities of affected communities, damaging lives and property. Globally floods are the most frequently occurring destructive natural event affecting both rural and urban settlements (Jha et al., 2012).

2.1.1 Understanding Flood Damages

Flood damages refer to all varieties of harm caused by flooding. It encompasses a wide range of harmful effects on humans, their health and their belongings on public infrastructure, cultural heritage, ecological system, industrial production and the competitive strength of the affected economy. Flood damages differ occasionally but are mostly categorized firstly into direct and indirect damages and secondly, Tangible and intangible damages (Parker et al., 1987; Pennizing Rowsell et al., 2003; Messner and Meyer, 2005).

The research works of (Parker et al., 1987; Penning Rowsell et al., 2003; Messuler and Meyer, 2005) explain that direct flood damage covers all varieties of harms which relate to the immediate physical contact of flood water to humans property, and the environment. This includes for example damage to buildings, economic assets, loss of standing crops and livestock in agriculture, loss of human life, immediate health impacts and loss of ecological goods.

Indirect flood damages are damages caused by disruption of physical and economic linkage of economy and the extra costs of emergency and other actions taken to prevent flood damage and other losses. But damages which can be specified in monetary terms such as loss of production are called tangible damages and those that cannot be valued in monetary terms such as casualties, health effects and damages to ecological goods which are not traded in the market are for more difficult to assess in monetary terms.

Quantification of flood damages is quite difficult as it has other developed issues year after. But flooding and its damages in global, national and district perspectives are discussed below.

2.1.2 Flooding in Global Perspective

According to Cunningham and Cunningham (2011) flood occur when it's flow of a stream becomes so great that it exceeds the capacity of its channel and overflows it's banks. They further indicated situation where torrential rains in June 2008 caused massive flooding across the American Midwest, where many cities in Iowa, Wisconsin, Illinois and Indiana experienced their highest water levels in more than a century. In Cadar Rapids, Iowa, for example, almost the entire downtown was inundated by the over flowing Cadar River,

2.1.3 Flooding in Nigeria

Floods are an extreme naturally occurring weather event that result in an overflowing of large amount of surface water over land that is not always inundated (Adeoye et al., 2009). It is considered to be the worst natural disaster in the world and it is responsible for a third of all natural problems and half of damage on facilities around the globe. It has become one of the most frequent natural occurrences in the last few decades (Jeb and Aggarwal, 2008).

Floods have cost damages to societies totalling more than 250 billion dollars and the intensity and frequency of floods are increasing globally. It is gradually becoming a common phenomena around the world, caused by increase in global temperature that result in torrential rains and rise in sea level that over flowed their banks and flood surrounding coastal lands (Jeb and Aggarwal, 2008).

In Nigeria, aside from droughts, floods cause almost 90 percent of damages resulting from natural hazards (Adeoye et al., 2009). Floods that occur in Nigeria are as a result of extensive rainfall, drainage blockage and dam failure (Jeb and Aggarwal, 2008). The effect of floods in Nigeria has been on the increase especially in the last three decades. It has become a life threatening concern to the citizenry and the number of deaths and damages caused by this perennial disaster are alarming.

The Federal Government of Nigeria in its own part has invested millions of dollars both on the relief and compensation as well as rehabilitation of flooded area yet the menace is still unabated (Jeb and Aggarwal, 2008). These days, flooding is fast becoming a serious environmental problem resulting in huge loss of lives, property price less arable land. Floods have rendered many people homeless and disrupted a lot of socio – economic activities in both urban and at rural areas. Various flood plains and land along the Atlantic Ocean coast, raves or lake are affected by flooding yearly in Nigeria (Jeb and Aggarwal, 2008).

2.1.4 Forms of Flood in Nigeria

According to Jeyaseelan, (1999), floods are of different forms and stunobe (2011) and Adeoye et al., (2009) have also mentioned that these forms of floods occur throughout Nigeria. They include the following: -

- a. *River Floods*: These floods which normally take place in the flood plains of the big stream and rivers are product of winter and spring heavy rains, completed with snow melt in upstream areas, and torrential rains from decaying tropical storms and monsoons (Jeyaseelan, 1999; Etuonovbe, 2011; Adeoye et al., 2009;; APFM, 2008).

These floods happen after rains cause river levels to rise and runoff volumes exceed normal surface flow capacities. The rise in river levels continue slowly and the period between rise and fall may last for a weeks or even a month especially in deltaic area (APFM, 2008).

- b. *Coastal Floods*: They are floods that normally occur in low-lying part of mangrove and fresh water swaps located

along coastal area generated by winds from intense off – shore storms and Tsunamis (Jeyaseelam, 1999; Etuonovbe, 2011; Adeoye et al., 2009).

- c. *Urban Floods*: As the name implies take place in urban areas especially in towns located on flat and low lying terrain especially where drainages are not available or poorly built or have been blocked by disposed municipal waste and eroded soil material. Conversion of natural terrain to paved and tarred roads increased runoff two to six times more than would normally occur (Jeyaseelam, 1999; Etuonovbe, 2011; Adeoye et al., 2009). Apfm (2008) has also mentioned that paved and tarred surfaces in urban areas cause high temperatures and create circulation of hot air locally referred to as “urban heat is land”. This hot air attract just particulars that act as nuclei for cloud moisture condensation process and form rain droplets that could develop into stronger and bigger rain drops of an unforeseen thunder storm (APFM, 2008).
- d. *Flash Floods*: These are related to rivers in inland areas and can occur within a short period of excessive rainfall or a dam or levee failure or dam spills or a release of water (Jeyaseelam, 1999; Etuonovbe, 2011; Adeoye et al., 2008). Flash floods are normally identified by their sudden rise in water levels followed by rapid decrease causing high flow velocities that can be very destructive especially in density populated area (APFM, 2008). Flash floods are very unpredictable and move with an unusual strong current carrying high volume of rubbles, sediments and dust and causing destruction/devastation to communities and infrastructures that stand along its path (APFM, 2008). This type of flood is experienced in Oguta, The Study Area.

2.1.5 Causal Factors of Flooding in Nigeria

According to Jonkman Nilsson, Factors that lead to flooding have been grouped into three main categories viz.:

- a. *Metrological* – Relating to extensive torrential rainfall, cyclones, storms and tidal surges.
- b. *Hydrological* – Relating to floods caused by increased surface run off as a result of and snow melt, land saturation, impermeable surface and land erosion.
- c. *Anthropogenic* – Concerned with human and natural activities such as population growth, urbanization, climate change, land use and degradation (ADPC, 2005).

A lot of researchers and papers have been written on the menace of flooding in Nigeria and some of the causal factors identified indented high river levels, land inundation from heavy rainfall, poorly built drainages with limited space and blockage of drainages from wastes materials, population growth, urbanization and climate change (Oriola, 1994; Ishaya et al., 2008; Akubanu et al., 1996; Folorunsho and Awosika 2001, Adeoye et al., 2009; Ologunrisa, 2004).

These factors are not independent of one another and flooding normally occurs as a result of a combination of one or more of these factors (Adeoye et al., 2009). Growth in population alongside economic and technological advancement have led to an increase in the need for more basic amenities such as shelter, food and the for desire for higher standard of living thus encouraging exploitation of the environment (Akinbami et al., 1996).

Most of the population explosion witnessed in developing countries is the urban centers and this is as a result of the shift from rural to urban centers because of the perceived improvement in living conditions in these urban areas (Ishaya et al., 2008). The unseen consequences of this shift and explanation are unsustainable use of environmental resources, environmental pollution that lead to change s in the state and course of the natural biosphere, breakdown of most environment and biological processes that support life and sustain development, variability in climatic conditions, degradation of soil and vegetation as well as conversion of agricultural land, natural vegetation and wet lands to built-up environments to contain the ever growing no of industrial and residential estates and buildings on natural

drainages (Ifatimehin et al., 2009; Ishaya et al., 2008; Akinbami et al., 1996).

Deforestation/removal of vegetation have increased the amount of run – off on land surfaces while agricultural activities affect soil compositions making them very compact, highly impermeable and reduce water infiltration (ADPA, 2005).

Flooding and other natural disaster could be future consequences of degradation of the environment and climate change (Ifatimehin et al., 2009; Yahaya et al., 2010; Jeyaseelan, 1999). According to Yahaya et al., (2010), these factors have intensified the frequency and severity of this natural hazard. Though studies have shown the extent of caused by flooding and some have tried to suggest possible ways of mitigating against it (Ologunorisa, 2004; Ologunorisa and Abawua, 2005; Dogunorisa, 2009; Folorunsho and Awosika, 2001), yet urban flooding is still an annual trend is because of the ever increasing shift of people from rural areas to urban cities for better livelihood hence increasing the population of those living in flood vulnerable areas such as flood plains and river beds.

2.1.6 Flood Risk Mapping

Area at risk of flooding can be dynamic in nature. With a changing level of development the nature and degree of risk also changes (Jha et al., 2012). Jha, et al., (2012) explained that flood risk increases mainly because of an increased level of exposure of the elements under threat. For example, there are occasions when infrastructure or other buildings are constructed in area already at risk, thereby automatically falling within a risk zone. There are also instances, when at the time of construction, the assets and infrastructures are thought to be outside the risk region, but there are newer affects arising from changing land uses as urban development proceeds. These can include increased rates of runoff, lack of drainage system, lack of storage system, overwhelming amount of rain fall leading to over flow, and the channelization of rivers which may reduce the amount of discharge they can accommodate (Jeb et al., 2012). All these factors can increase the number of elements at risk of flooding in an area continuous updating and monitoring of risk maps is therefore, most important for proper flood risk management. Decision – makers need up to date

information in order to allocate resources appropriately. It has been argued that, even without an increase in flood hazard over time, the impact of flooding has risen (and will continue to rise) because of the increase exposure of primary and secondary receptors (Jha et al., 2012).

2.1.7 Management and Control of Floods in Nigeria

The government of Nigeria are the primary initiators of measures for the management of flooding in Nigeria. Various institutions, policies and regulations have been set up by government to address issues relating to floods and activities that promote/influence flooding in Nigeria (Oladipo, 2010). They include;

a. National Environmental Standards and Regulations Enforcement Agency (NESREA)

This is an agency of the Federal Ministry of Environment that is saddled with the responsibility of enacting and enforcing regulations that protect the environment from degradation (Oladipo, 2010). Examples of some flood – related regulations are;

- i. Water shed, Mountain, Hilly and Catchment area Regulations 2009: To check and restrain activities in the above – mentioned areas that are inconsistent with proper land practices (Oladipo, 2010).
- ii. Wetlands, River Banks and Lake Shores Regulations 2009: The objectives of these regulations are management and conservation of water catchments and flood control, conservation and sustainable use of wetlands and pollution control (Oladipo, 2010).

b. National Erosion and Flood Control Policy (NEFCP), 2005

“The goal of the National erosion and flood control policy (NEFCP) of 2005 is to protect the environment from degradation loss of productive land and negative impacts of flood. Ensure coordinated and systematic measures in the management and control of the hazards of erosion and floods to reduce their impacts on the people and the environment” (Oladipo, 2010).

c. National Emergency Management Agency (NEMA)

NEMA is a Federal Government agency that is responsible for co-ordinating, managing and

controlling disaster related activities in the country (NEMA, 2011). Since the inception of these various agencies, polices and regulations, the country’s responses to flood risk management has still been mainly that of relief management after a flooding incident, even then, coordination of rescue operation have always been slow exacerbating the damage and loss in the aftermath of the event (NEMA, 2011; Job and Aggarwal, 2008). Part of this problem may be due to lack of technical expertise for handling environment issues and insufficient information on flood vulnerability of different parts of the country, hence, the need for introducing proven strategies for combating this menace.

2.2 Remote Sensing, GPS and GIS in Flood Risk Mapping and Management

Remote sensing is the technology that is used in gathering of the spatial information used for identifying, classifying, mapping, monitoring, planning, mitigation and management of natural disasters (Ishaya and Ifatimehin, 2009, Jeyaseelan, 1999). This technology has been used extensively in Asian and developing countries for agricultural, aviation, and environmental purposes (Ishaya and Ifatimehin, 2009).

For an effective flood risk management plan, it is becoming very important to provide flood risk maps that show different vulnerable areas and the potential adverse consequences of different flood risk map. Information on important criteria for flood risk analysis including elevation, slope orientation, closeness of built up areas to drainages, drainage network and density, presence of buffers, extent of inundation, land cover / land use information, rainfall data, cultural practices as well as attitudes and perceptions are needed for mapping studies (Ishaya et al., 2009; Tanavud et al., 2004).

Remote sensing and GIS provide the tool for assessing these information (Auggel et al., 2003) and have proved to be an effective and perhaps suitable choice in flood hazard preparedness and reduction of potential risk. These digital maps must take into recognition the environmental factors leading to floods (Forte et al., 2006). The different data sets gotten from remote sensing can be integrated into Geographic Information System (GIS) to create map that shows vulnerability of a

location to natural disaster such as flooding, (Ishaya and Ifatimehin, 2009; Dewan et al., 2006).

2.2.1 Fundamental Principle of Remote Sensing

Remote sensing systems or sensors basically measure and record electromagnetic energy emitted or reflected from the object of study. Electromagnetic energy refers to all energy that moves with velocity of a light in a simple harmonic wave pattern. In other words, electromagnetic energy propagates in a sinusoidal form. It can only be detected in terms of its interaction with matter. Visible light, radio waves, heat, ultraviolet rays, x-rays etc. are forms of electromagnetic energy.

Electromagnetic wave can be described in terms of their velocity, wavelength and frequency.

$v = \lambda f$, where v = velocity of electromagnetic energy in a vacuum (299, 793 km per second or 3×10^8 m per second)

f = the frequency of the energy

λ = the wavelength of the energy.

2.2.2 Interaction between Electromagnetic Energy and Matter

Electromagnetic energy does not interact with itself rather it interacts with matter. The nature of this interaction is a function of the physical or chemical structure of the matter and the wavelength of the energy. Fundamentally, if the wavelength of the energy is known, then the characteristics of the matter can be determined by the nature of the interaction. (Ndukwe, 1997).

Two types of interaction between energy and matter may be distinguished, namely surface phenomena (interactions that take place at the surface of a substance) and volume phenomena (interactions that involve penetration of electromagnetic radiation). For example, it can change its magnitude, direction, strength etc. When electromagnetic energy is incident on any given earth surface feature, the following fundamental energy interactions with the features are possible.

Reflection: the radiation may be reflected or turned unchanged from the surface of the substance with angle of reflection equal and opposite to the angle of incidence.

Absorption: the radiation may be absorbed by the substance and its energy given up largely to the heating the substance.

Transmission: The radiation may be transmitted, that is it may pass through the substance.

The ratio of the initial velocity called index of refraction is expressed as follows:

$\zeta = \frac{v_a}{v_s}$ where ζ = index of refraction

v_a = velocity in the air

v_s = velocity in the substance.

Emission: the absorbed radiation may be re-emitted (usually at a longer wavelength) by the substance as a function of its structure and temperature.

Scatter: the radiation may be scattered. This implies, the deflection of the energy in all directions within the substance, can be considered as the energy lost to the system.

The interaction may be with some combination of the above phenomena. The energy/ matter interaction mechanism is illustrated with an element of volume of water. It is these interactions between matter and energy that provide the physical basis for remote sensing of the environment. The remote sensor detects and records the result or changes produced by these interactions. The resulting images and data are interpreted to identify remotely the physical and chemical characteristics of the matter that produce the changes in the recorded electromagnetic radiation. Hence, the subject of remote sensing deals with interactions between matter and electromagnetic radiation of different wavelength bands together with the technology employed in sensing the interaction and in interpreting the data (information) obtained. It must be noted that the proportion of energy reflected, absorbed or transmitted will vary for different earth features, depending upon their material type and conditions such as their atomic and molecular structure or composition.

These differences permit us to distinguish between difference features on an image. Again, the proportion of reflected, absorbed or transmitted energy will vary at different wavelength bands. Within the visible portion of the spectrum, these spectral variations result in the visual effect called colour.

3. METHODOLOGY

It involves the overall methods, approaches and materials adopted. It mainly explains the data sources and types, methods of field data collection, reference data used, identification, image classification technique, weighted Analysis employed, accuracy assessment, statistical analyses and list of software packages used to achieve the research objective. The flowchart for the methodology followed in this study is shown in figure 3.1

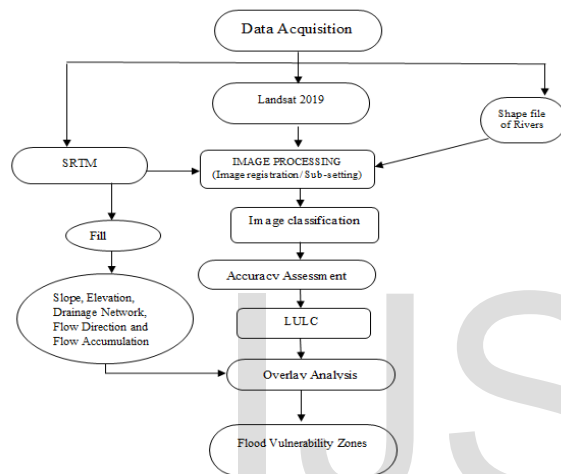


Figure 3.1: Methodology Flowchart

3.1 Data Requirement

Data required in this research includes:

- i. Landsat 8 OLI imagery covering the study area
- ii. Shuttle radar topographic mission (SRTM) covering the study area.
- iii. Shape file of the administrative boundary of Rivers State

3.2 Data Acquisition

3.2.1 Acquisition of Primary Datasets

These data were obtained through field visits peculiar to the research at hand. They include

- i. The coordinates of sample points of land cover/ landuse to be used for accuracy assessment was obtained using handheld GPS.
- ii. Non-spatial (attribute) data describing the characteristics of Land cover/ land use identified on the scene was collected.

3.2.2 Acquisition of Secondary Datasets

The secondary datasets needed was obtained from already existing medium. They include:

- i. Shape file of the administrative Rivers State, which was obtained from the Department of Surveying & Geoinformatics, Nnamdi Azikiwe University Awka.
- ii. Landsat 8 OLI imagery, this was downloaded from www.earthexplorer.usgs.gov.
- iii. SRTM Image, this was downloaded from www.earthexplorer.usgs.gov

3.3 Hardware and Software Requirements

3.3.1 Hardware Requirements

The hardware components include the equipment used for the execution of the research and they include:

- i. a computer system with sufficient memory and processing capability.
- ii. a scanner for scanning analogue maps
- iii. a printer for presentation of the result in hardcopy format.

3.3.2 Software requirements

The following software was used for this study:

- i. ArcGIS Software version 10.2: this was used for vectorization, image subset, spatial analysis, overlay Analysis and Flood vulnerability mapping
- ii. Erdas Imagine 2014: this was used for classification and Accuracy assessment
- iii. Microsoft suite: this was used for performing the task of editing and production of text report.

3.4 Processing technique

This involves the techniques that were adopted in order to achieve the research objective.

These techniques involve the following:

3.4.1 Image Sub-Mapping

This process was carried out in order to cut out the area of interest from the satellite image and SRTM using the shape file of Rivers State extracted from the administrative boundary of Nigeria local government area. This was achieved using the ArcGIS 10.2 software as shown in fig 3.2.

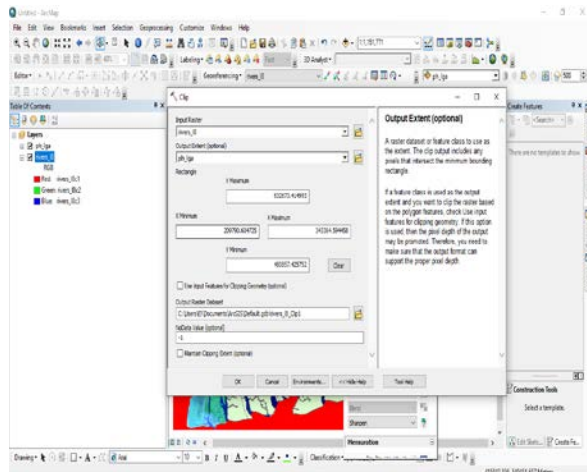


Figure 3.2: Clip tool in Arc Toolbox

3.4.2 Definition of class categories

This was done to identify and define various class features on the scene before following a familiarization visit to the site. Thus, the following class features in Rivers State L.G.A were identified and defined according to level 1 classification scheme; this scheme was adopted because of the resolution of the image sets and to ensure that the features are discriminated adequately.

- i. Built up Area
- ii. Water Body
- iii. Vegetation
- iv. Mangrove
- v. Farmland
- vi. Open Space

3.4.3 Ground Truthing

This exercise was carried out after definition of class categories in order to identify the features on the ground and collect sample points for accuracy assessment.

3.4.4 Image Classification

Digital image classification uses spectral information represented by the digital numbers in one or more spectral bands and attempts to classify each individual pixel based on its spectral information. In this study, the images were classified using the supervised classification method. The classification as shown achieved through the following procedure:

- i. Clicking on the classify function on the tool bar
- ii. Then select the Signature Editor
- iii. Then using the signature editor select signature set of the various classes

- iv. Then select the supervised classification method to classify using the signature set selected
 - v. Change the processing options if need be
- Then click on "ok" to perform the classification

3.4.5 SRTM Processing

SRTM is a topographical model with elevation records of cells in certain size. However, there is still potential of existence off sunken areas because of data error or landform Karst Topography. Data error is mainly caused by the resolution limitation of DEM on both vertical and horizontal direction and system error during the generation of DEM. Due to existence of these sinks, unreasonable flow direction may be generated during the calculation. If these sinks are not filled by technical process, then the generated drainage network will not be continuous.

The process of filing sink is called elevation smoothing or filling depressions. The main purpose of elevation smoothing is to reduce the number of artificial depressions generated by data collection system. The most used procedure of sink fill, taken as the official algorithm in the most wide-used GIS software ArcGIS.

The SRTM was processed to fill the sinks present in the elevation dataset; this was done with spatial analyst tool in ArcToolbox. Since water flows from higher to lower elevations and slope influences the amount of surface runoff and infiltration, and also Flat areas in low elevation may flood quicker than areas in higher elevation with a steeper slope. Areas of concentrated surface water, river overflows are crucial for the initiation of a flood event. Often the inundation emanates from riverbeds and expands in the surroundings. Flow accumulation is the most important parameter in defining flood hazard. Accumulated flow sums the water flowing down slope into cells of the output raster. High values of accumulated flow will indicate areas of concentrated flow and consequently higher flood hazard.

With this, the classified elevation, slope gradient, flow accumulation, drainage networks were created. This was done in preparation for the weighted layers needed for analytical hierarchy process analysis.

3.4.6 Overlay Analysis

This analysis was used to create flood hazard zones by assigning weight of importance to the layers created. The weighted layers are then overlaid, and a Comparison intersect matrix is performed to produce flood vulnerability zones for the study area. The final calculation is done in ArcGIS raster calculator.

4. RESULTS PRESENTATION AND DISCUSSION

In this section, results of image analysis as obtained from the classification procedure of supervised classification and flood mapping are presented. Most of the discussions are supported by maps, tables and illustrative graphs.

4.1. Land cover / Land use Mapping

4.1.1 Land cover / Land use Distribution of Rivers State 2019

In mapping land cover/land use, four different classes were identified to include Built up areas, vegetation, open space, farmland, mangrove and water bodies. The classified image of Rivers State is shown in figure 4.1

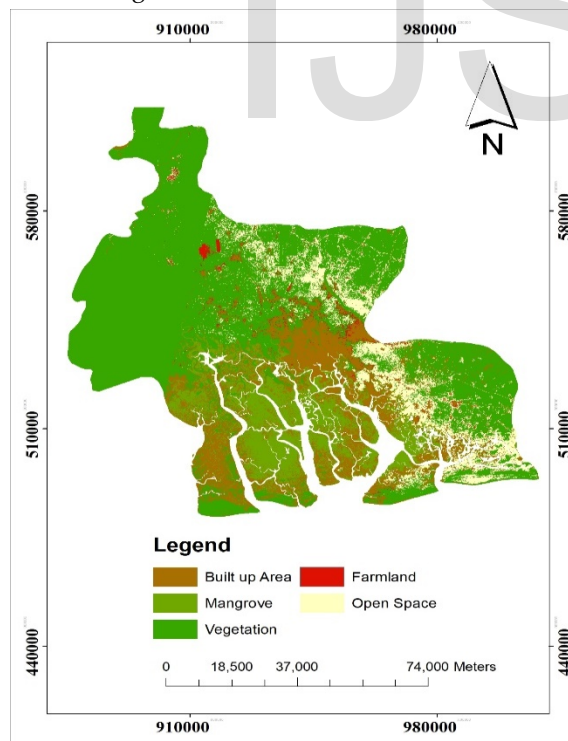


Figure 4.1: Land cover / Land use map of Rivers State

Figure 4.1 shows the results of the land cover/land use classification of Rivers State, the results indicate that vegetation accounted for the largest land cover/use of about 37.23 % with an area of 4096 km² while built up area had the second largest with 31.48 % and an area of 3463 km², water body had 11.51 % with an area of 1267 km², open space had 9.78 % with an area of 1076 km² and mangrove had 9.98 % with an area of 1098 km². The land cover / land use distribution is shown in table 4.1 and figure 4.2

Table 4.1: Land cover /Land use distribution of Rivers State

Class Name	Area (Km ²)	Percentage (%)
Vegetation	4096	37.23
Built up area	3463	31.48
Water body	1267	11.51
Open Space	1076	9.78
Mangrove	1098	9.98
Total	11000	100

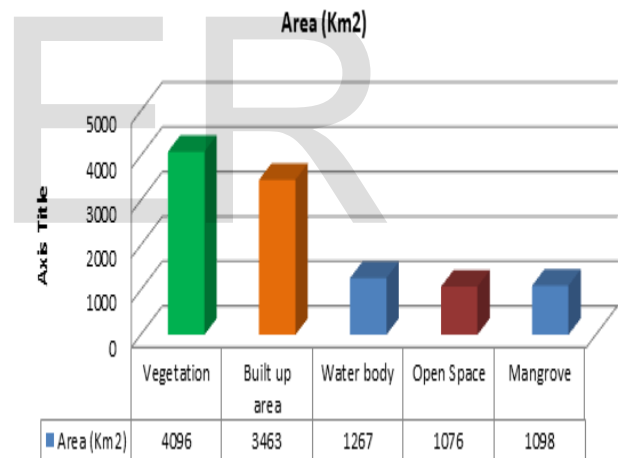


Figure 4.2: Histogram of land cover / land use distribution of Rivers State

4.2 Accuracy Assessment and Kappa Statistics

In remote sensing-land cover mapping study, classification accuracy is most important aspect to assess the reliability of the final output maps. The main purpose of assessment is to assure classification quality and user confidence on the product.

Kappa statistics was done to measure the level of agreement of the classification of the class categories, kappa is always less than or equal to 1. A value of 1 implies perfect agreement and values less than 1 implies less than perfect agreement.

Interpretations of kappa

- i. Poor agreement = Less than 0.20
- ii. Fair agreement = 0.20 to 0.40
- iii. Moderate agreement = 0.40 to 0.60
- iv. Good agreement = 0.60 to 0.80
- v. Very good agreement = 0.80 to 1.00

From the results gotten from the Classification Accuracy Assessment Reports and Kappa (K^{\wedge}) statistics for the image, it shows a very good accuracy and also a very good agreement on the Kappa statistics. The result of the classification accuracy assessment report and kappa statistics for the classified image of Rivers State is shown in table 4.3.

Table 4.3: Accuracy Assessment Reports and Kappa (K^{\wedge}) Statistics for Rivers State Classification

Accuracy totals			Kappa (K^{\wedge}) statistics
Class Name	Producers Accuracy	Users Accuracy	Kappa
Vegetation	92.66%	95.45%	0.9405
Built up area	90.67%	87.38%	0.8902
Water body	100.00%	88.00%	0.9400
Open space	98.00%	85.44%	0.9172
Mangrove	76.56%	85.14%	0.8085
Totals			Overall K^{\wedge}
Overall Classification Accuracy = 85.99%			0.8992

4.3 SRTM Processing

4.3.1 Filling Sinks

SRTM is a topographical model with elevation records of cells in certain size. However, there is still potential of existence off sunken areas because of data error. Data error is mainly caused by the resolution limitation on both vertical and horizontal direction and system error during the generation of DEM. Due to existence of these sinks, unreasonable flow direction may be generated during the calculation. If these sinks are not filled by technical process, then the generated drainage network will not be continuous. The main purpose

of elevation smoothing is to reduce the number of artificial depressions generated by data collection system. The results achieved by filling the sinks in the SRTM is shown in figure 4.3

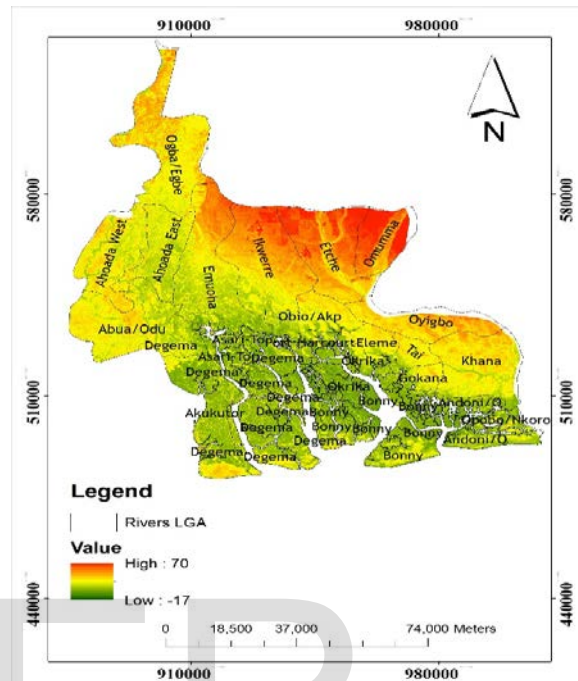


Figure 4.3: Filled SRTM

4.3.2 DEM and slope Reclassification

After the SRTM was filled, Dem was reclassified into the following elevation class as shown in figure 4.3

- i. -17-20m (High Risk)
- ii. 20m-30m (moderate Risk)
- iii. 30m-40m (low Risk)
- iv. 40m-70m (no Risk)

These categories of risk were created based on the elevation and ground information obtained within the catchment.

The SRTM was also used to create the slope gradient of the study area. The slope gradient obtained from the SRTM was reclassified using the following five classes based on Food and Agricultural Organization (FAO) classification of slopes (www.fao.org):

- (a) 0-2% = Flat (High Risk)
- (b) 2-8% = Undulating (moderate Risk)
- (c) 8 -16% = Rolling (low Risk)
- (d) 16 -32% = Hilly (no Risk)

4.3.4 Flow Accumulation

Flow accumulation is a process that assigns every cell with a value equals to number of cells flow into it. To be specific, the process of flow accumulation is based on the data of flow direction and rules below are followed.

1. Starting from the first cell, tracks cells along the flow direction until a stop point (lowest elevation in 3*3 matrix) of flow or edge of DEM.
2. Cells along the tracking route gain 1 accumulated value;
3. When cross with tracking routes, the accumulated value of the other tracking route is added to current tracking route.
4. Calculation stops when each cell in flow direction data matrix is calculated.

Catchment area can be calculated by multiplying value in accumulated flow matrix with the area of a single cell. Since areas of concentrated surface water, river over-flows are crucial for the initiation of a flood event and often the inundation emanates from riverbeds and expands in the surroundings. Flow accumulation is the most important parameter in defining flood hazard. Accumulated flow sums the water flowing down slope into cells of the output raster. High values of accumulated flow will indicate areas of concentrated flow and consequently higher flood hazard.

4.3.5 Distance from Drainage Networks

The drainage channels are defined as cells with accumulated flow exceeding a user-defined threshold. Different methods of quantitative description of drainage networks are studied by many researchers. The most used are Strahler method (Strahler 1957) and Shreve method (Shreve 1966). In both of these methods, drainage network is idealized as a tree with a strong root and slimmer branches, but the identification of different levels of branches are not the same within these two methods.

Strahler method follows the rules below (Strahler 1957)

1. Level I is assigned to those streams without any branch
2. Level II is assigned to downstream where two of the level 1 upper streams meet

3. Level n is assigned to downstream where two of the level n-1 upper stream meet
4. If two upper streams with different levels meet, then the downstream is assigned with the higher level in the two upper streams.

Shreve method also follows the same rule for the level I stream assignment but for others levels, the rules are different. When a level n upper stream meets a level m upper stream, the downstream is assigned with level n+m, that is to say, when all streams ideally flows to the same outlet, then the level value of the last downstream, where outlets is, equals to the last amount of level streams(Shreve 1966).

Apart from areas of concentrated surface water, river-overflows are crucial for the initiation of a flood event. Often the inundation emanates from riverbeds and expands in the surroundings. The role of riverbed decreases as the distance increases. That explains why "distance from the drainage network" has been assigned a high weight in the methodology. It appears that areas near the river network < 200 m are highly flood hazard, whereas the effect of this parameter decreases in distances > 2000 m. therefore a Boolean distance buffer was created for 200, 500, 800 and 1000 representing high risk, moderate risk, low risk and no risk areas.

4.4 Overlay analysis

An overlay analysis was conducted by overlaying all reclassified factors against each other. The resulting layer indicated the intersection between the various risk classes. This intersection defined the risk vulnerability in the study area.

4.5 Flood Vulnerability Zones

The results of the overlay analysis produced a layer showing four hazard zones; namely high vulnerability, moderate vulnerability and low vulnerability and no vulnerability flood zones in the study area.

The results indicated that high-vulnerability zone occupied 28.60% of the entire study area, covering an area of 3147km², while moderate vulnerability zone occupied 27.28%, covered an area of 3001km². Low vulnerability zone occupied 27.05% covering 2976km² while no vulnerability zone occupied 17.05% covering an area of 1876km². This

is distribution is also represented in table 4.4 and figure 4.4

Table 4.4 Flood hazard zone distribution

Class Name	Area (km ²)	Percentage (%)
High Vulnerability	3147	28.60
Moderate Vulnerability	3001	27.28
Low Vulnerability	2976	27.05
No Vulnerability	1876	17.05
Total	11000	100

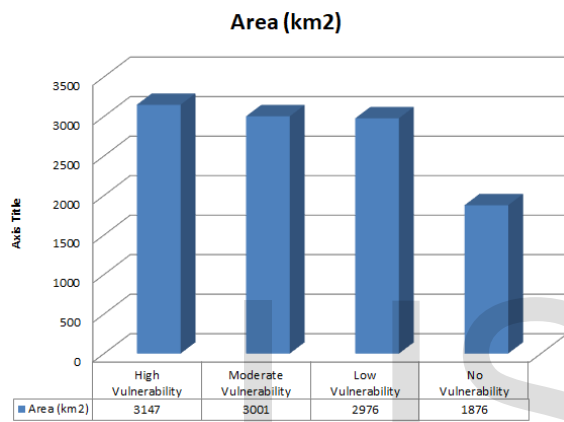


Figure 4.4: Histogram of flood vulnerability distribution

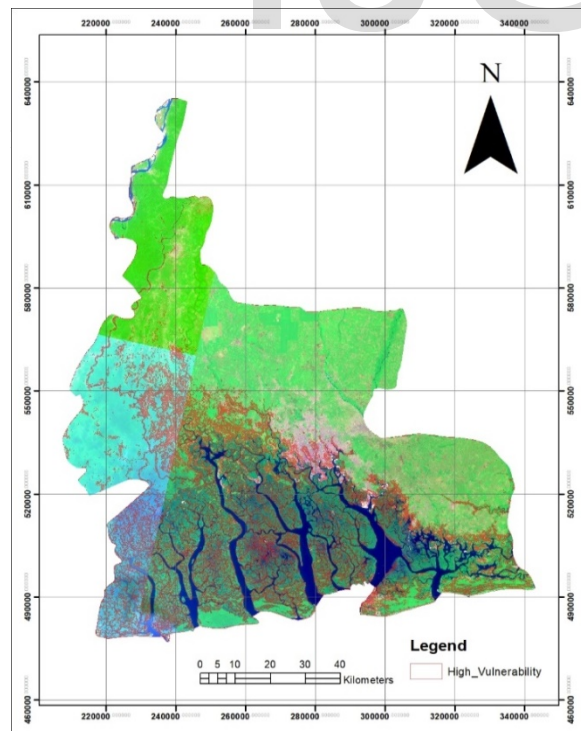


Figure 4.5: Feature class at high vulnerability flooding

The results showed that vegetation occupied the largest area in high vulnerability flood zone with an area of 628km², followed by built up area covering an area of 525km², while water body and mangrove occupied 1007km² and 987 km² respectively. The distribution of class within the very high vulnerability flood zone is shown in table 4.5

Table 4.5: Distribution of feature class at high vulnerability flooding

Land cover/Land use Class at Vulnerability Flooding		
Class Name	Area (km ²)	Percentage (%)
Vegetation	628	19.95
Built up area	525	16.68
Water body	1007	31.99
Mangrove	987	31.36
Total	3147	100

b. Features at vulnerability of moderate flooding

The overlay results showing feature class at Moderate vulnerability is shown in figure 4.6

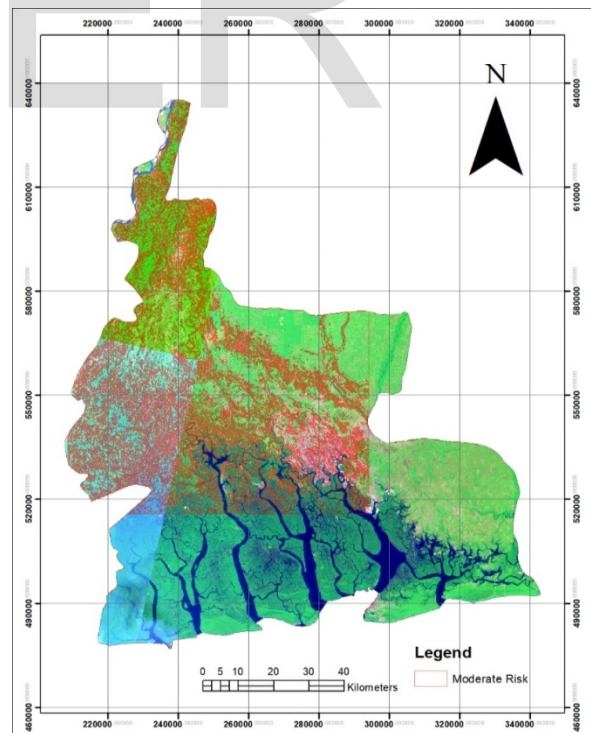


Figure 4.6: Feature class at moderate vulnerability flooding

The results figure 5.10 indicates that built up area occupied the largest area in moderate vulnerability flood zone with an area of 1275km², followed by vegetation covering an area of 1015km². While water body and open space occupied 252 and 459 km² respectively. The distribution of class within the moderate vulnerability flood zone is shown in table 4.6

Table 4.6: Distribution of feature class at vulnerability of Moderate vulnerability flooding

Land cover/Land use Class at moderate Vulnerability Flooding		
Class Name	Area (Hectares)	Percentage (%)
Vegetation	1275	42.48
Built up area	1015	38.82
Water body	252	8.39
Open space	459	15.29
Total	3001	100

c. Features at low vulnerability flooding

The results for feature class at low vulnerability flooding indicate that vegetation occupied the largest area in moderate vulnerability flood zone with an area of 1514km², followed by built up area covering an area of 1295km². While water body and open space occupied 67 and 100km² respectively. The distribution of class within the moderate vulnerability flood zone is shown in table 4.7

Table 4.7: Distribution of feature class at moderate vulnerability flooding

Land cover/Land use Class at vulnerability of low Vulnerability Flooding		
Class Name	Area (Hectares)	Percentage (%)
Vegetation	1514	50.87
Built up area	1295	43.51
Water body	67	0.67
Open space	100	3.36
Total	2976	100

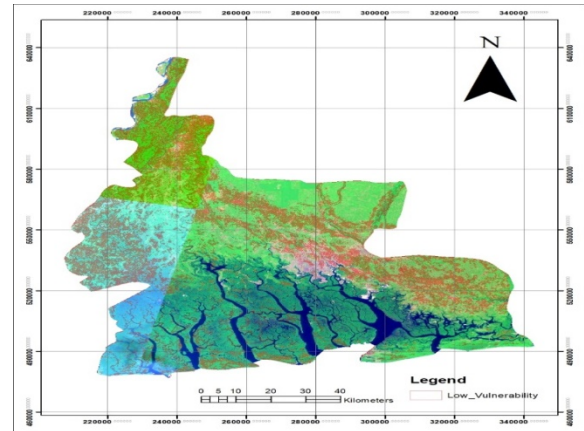


Figure 4.7: Feature class at low vulnerability flooding

d. Features at no vulnerability flooding

The results for feature class at no vulnerability flooding indicate that vegetation occupied the largest area in no vulnerability flood zone with an area of 975 km², followed by built up area covering an area of 699km². While water body and open space occupied 67 and 135 km² respectively. The distribution of class within the no vulnerability flood zone is shown in table 4.8

Table 4.8: Distribution of feature class at low vulnerability flooding

Land cover/Land use Class at no Vulnerability Flooding		
Class Name	Area (Hectares)	Percentage (%)
Vegetation	975	51.97
Built up area	699	37.26
Water body	67	3.57
Open space	135	7.19
Total	1876	100

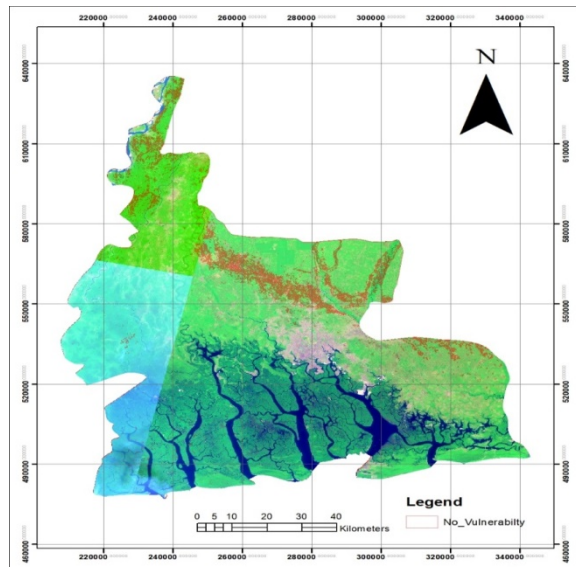


Figure 4.8: Feature class at vulnerability of low vulnerability flooding

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study aimed at investigating flood vulnerability in parts of Rivers State using flood Remote Sensing and GIS. Its objectives were to delineate different vulnerability levels of flooding in the study area, to determine the effect or impact of flooding on different land cover types and to produce flood vulnerability map of the study area. The methodology involves data acquisition, data processing and reclassification and overlay analysis. This study has been able display the usefulness of Remote Sensing and GIS technologies in classifying and in identifying areas with high, moderate, low vulnerability of flooding within the study area.

The classification achieved an overall Classification Accuracy of 85.99% and kappa statistics of 0.8992. The image classification results indicate that vegetation accounted for the largest land cover/use of about 37.23 % with an area of 4096 km² while built up area had the second largest with 31.48 % and an area of 3463 km², water body had 11.51 % with an area of 1267 km², open space had 9.78 % with an area of 1076 km² and mangrove had 9.98 % with an area of 1098 km². The flood vulnerability mapping results also indicated that high-vulnerability zone occupied 28.60% of the entire study area, covering an area of 3147km², while moderate vulnerability zone occupied 27.28%, covered an area of 3001km². Low vulnerability

zone occupied 27.05% covering 2976km² while no vulnerability zone occupied 17.05% covering an area of 1876km².

5.2 Recommendations

Based on the results and analysis obtained, the following recommendations were made:

- i. the vulnerability maps produced in this research are beneficial and are recommended that they be used in encouraging vulnerability zone residents to prepare for the occurrence of flooding.
- ii. It is recommended that the results achieved in this research can be used as a base to help identify areas at vulnerability of being flooded in the study area.

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