

**APPLICATION OF REMOTE SENSING IN FLOOD MONITORING
OF IKPOBA-OKHA LOCAL GOVERNMENT AREA**



BY

AIGBOKHAODE DAVID IMOHIOSE

MAT NO: ENV1604536

2022

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**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF
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2022

CERTIFICATION

This is to certify that this project was carried out by **AIGBOKHAODE DAVID**
IMOHIOSE with the Matriculation number ENV1604536 of the Department of Geomatics,
Faculty of Environmental Science, University of Benin, Edo State, Nigeria.

SUPERVISOR

SURV M. O. EKUN

Date

HEAD OF DEPARTMENT

SURV M. O. EKUN

Date

EXTERNAL EXAMINER

Date

DEDICATION

This Project is dedicated to God Almighty and to my parents Mr. & Mrs. Aigbokhaode.

ACKNOWLEDGEMENT

All thanks, adoration, honour and glory be unto Almighty God. For His unending love towards me, His infinite mercy, guidance, grace, and opportunity given to me to move forward against all odds and for the successful completion of this project and my B.Sc. program in the department of Geomatics, University of Benin.

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ABSTRACT

Flooding generally is one of the major natural disasters anywhere around the globe. The effect of flood has led to major losses including human, property, infrastructure and economic losses. Due to climatic conditions, the impact of flood has greatly increased over the years. Remote Sensing is a technique to observe the earth surface or the atmosphere from out of space using satellites (space borne) or from the air using aircrafts which are airborne.

The satellite imagery of the project area was downloaded from United State Geological Survey (USGS). The imagery was screened and the data was extracted using the ARCGIS 10.4 software in order to determine the land use features and some other factors responsible for flooding in the study area. Domain definition, colour composite, image classification, creation of sample set, post classification comparison' and sub setting were carried out on the downloaded imagery. The processed imagery was used to identify bare land, built up areas, rocks and vegetation. The digital elevation model showing the unique features of the study area was also produced from this procedure. The land use map, the flood map, and the flood vulnerability map were also produced. Rainfall data were sourced geospatially from 2012 to 2020, this is to provide the rainfall pattern in the study area.

The result obtained from the study revealed that land use has changed significantly in the study area in the last ten years. The result showed that bare lands and vegetation are fast giving way from residential, large scale industries, commercial estates and other infrastructural development. From this, over 80% of arable lands are either paved or surfaces improved which is responsible for low water infiltration resulting in flooding. Within this period rainfall has also increased significantly from 2087mm in 2012 to 2674mm in 2020. This makes large proportion of the area vulnerable to flooding as showed in the flood map and vulnerability map of the study area. Proper flooding measures have to be put in place to prevent inundation of the study area.

TABLE OF CONTENTS

Title page	ii
Certification	iii
Dedication	iv
Acknowledgement	v
Abstract	vi
Table of Content	vii
List of Figures	x
List of Tables	xi
CHAPTER ONE	
1.0 Introduction	1
1.1 Background of Study	1
1.2 Statement of Problems	4
1.3 Aim and Objectives	5
1.4 Scope of Study	5
1.5 Justification of Study	5

CHAPTER TWO	6
2.0 Literature Review	6
2.1 Flooding	6
2.1.1 Flood Characteristics	6
2.1.2 Causes of Flooding in Nigeria	7
2.2 Types of Flooding	8
2.2.1 River Flooding	9
2.2.2 Coastal Flooding	9
2.2.3 Urban Flooding	9
2.3 The Flooding Report Around the World	10
2.4 Introduction to Methods of Monitoring Floods	12
2.4.1 Flood Probability	12
2.4.2 Floodplain Delineation	13
2.4.3 Flood Hazard Mapping	13
2.5 Effects of Flooding	15
2.5.1 Floods can Harm Wildlife	16
2.5.2 Floods Cause Sedimentation and Erosion	16
2.5.3 Flood Carry Contamination	16
2.5.4 Floods Spread Disease	17
2.5.5 Loss of Lives and Property	17
2.5.6 Loss of Livelihood	18
2.5.7 Decreased Purchasing and Production Power	18
2.5.8 Mass Migration	18
2.5.9 Psychosocial Effects	18
2.5.10 Hindering Economic Growth and Development	19
2.5.11 Political Implication	19
2.6 Recent Flooding in Nigeria	20
2.6.1 The Implication of the Floods on the 2023 Election	21

2.7	Methods and Techniques for Monitoring Flooding	23
2.7.1	Flood Probability	23
2.7.2	Flood Plain Delineation	24
2.8	Flood Hazard Mapping	25
2.8.1	Land Use/Land Cover	26
2.8.2	Rain Pattern	27
2.9	Flood Risk Management	28
2.9.1	Management Methods	29
2.9.2	Flood Mapping	30
2.9.3	Flood Modeling	30
2.9.4	Stakeholder Engagement	31
2.9.5	Implementation Measures	31
2.10	Remote Sensing	32
2.10.1	Flood Monitoring Using Sensing	36
2.11	Data Acquisition	39
2.11.1	Common Data Acquisition Considerations	39
2.11.2	Converted/Transformed Legacy Data Considerations	41
2.11.3	Shared/Exchanged Data Considerations	41
2.11.4	Considerations for Bought Data	42
CHAPTER THREE		43
3.0	Methodology	43
3.1	Study Area Description	43
3.2	Data Acquisition	44
3.3	Hardware and Software to be Utilized for this Project	44
3.4	Rainfall Analysis of the Study Area Calculation	45
3.5	Generating the DEM of the Study Area	45
3.6	Generating a Land Use/Land Cover	46
CHAPTER FOUR		51
4.0	Results and Discussion	51

4.1	Digital Elevation Map	51
4.2	Flood Risk Map	53
4.3	Land Use/Cover Map	55
4.4	Vulnerability Map	57
4.5	Calculation of Rainfall Analysis of the Study	59
4.6	Analysis of Flood Maps Generated	62
4.6.1	Land Use/Cover Map	62
4.6.2	Flood Risk Map	62
CHAPTER FIVE		63
5.0	Conclusion and Recommendation	63
5.1	Conclusion	63
5.2	Recommendations	64
REFERENCES		65

LIST OF FIGURES

Figure 2.1: Ikpoba-Okhas flooded region, (Akenzua 2020)	12
Figure 2.2: Electromagnetic wavelength diagram (Sanderson, 2014)	33
Figure 2.3: Remote sensing operation (Source: Hamakareem, 2019)	34
Figure 3.1: Study Area	44
Figure 3.6: Flow chart showing land use/cover process	47
Figure 4.1: Map showing the Digital Elevation Model of Ikpoba Okha L.G.A	52
Figure 4.2: Map showing flood Risk of Ikpoba Okha L.G.A	54
Figure 4.3: Map showing Land Use/Land Cover of Ikpoba Okha L.G.A	56
Figure 4.4: Map showing Vulnerability Map of Ikpoba Okha L.G.A	58

LIST OF TABLES

Table 4.1: Annual rainfall parameter (2010 -2018)	59
Table 4.2: Complete table of annual rainfall	60

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

A flood can be defined as an unusually high stage in the river, normally the level at which the river overflows its bank and inundates the adjoining/surrounding area. A sound definition of flooding is the overflowing or eruption of a great body of water over land not usually submerged. Flooding is considered a major and serious environmental problem confronting municipal authorities from development (Dehradun, 2007).

A flood can also be defined as a large volume which arrives at and occupies the stream channel and its flood plain in a time too short to prevent damage to economic activities including homes (Abam, 2006). Flood is also said to be an abnormal and progressive rise in the water level of streams or rivers which may result in overflowing (Anon., 2021). Over the years, flood has been one of the most frequent types of natural disaster as it occurs in almost all part of the world. Therefore, the desire to solve flood problems cannot be overemphasized. It is the most common of all environmental hazards regularly claims more than 20,000 lives per year and adversely affects approximately 75 million people worldwide. Generally, environmental problems such as pollution from fuel exploration and ozone depletion have been addressed mostly in developed nations and urban centres. However, flooding mostly induced by climatic hazardous events, especially in developing countries is still a major risk. Flooding is one of the natural disasters ravaging the African continent and Nigerian society (Geosciences, 2019).

Flooding reduces economic growth and development because of the high cost of relief and recovery associated with floods. In frequently flooded areas, there is less likely to be any investment in infrastructure and other developed activities. Flood tends to develop over days

when there is too much rainwater the river, stream or lake can contain as it has reached its limit, therefore, spreading over to land next to it (Geosciences, 2019).

A variety of climatic and non-climatic processes influence flood processes, resulting in river floods, flash floods, urban floods, sewer floods, glacial lake outburst floods, and coastal floods. These flood-producing processes include intense and/or long-lasting precipitation, snow melts via increased temperature and dam break, and reduced conveyance due to jams landslides or storms. Population growth has also been found to indirectly intensify flooding.

Flooding has caused significant damage worldwide. In 2004, the International Federation of Red Cross and Red Crescent Societies showed that during the 10 years from 1993 to 2002, flood disasters affected an estimated 140 million people globally per year on average, more than all other natural or technological disasters put together. There have been flooding disasters in various parts of Nigeria, as virtually all states have witnessed flooding at one time or another (Geoscience 2019).

The major cause of flooding has always been heavy rainfall, especially for areas experiencing steady rainfall, other causes also include, overflowing rivers, dam breaks, breaching of the embankment, drainage congestion, storm surge, glacial lake outburst, lack of vegetation etc. flood most times builds up gradually as it tends to cover a large area (Geosciences, 2019).

Flood disaster in Nigeria has done nothing but leave an unforgettable and devastating effect on its victims and areas affected, it is the most common environmental hazard in Nigeria (Samson, 2015) According to a Red Cross report on October 20th, over 150 persons lost their lives and approximately 25000 were displaced as a result of flooding that begun in September 2020.

Yobe state in northeastern Nigeria experienced flooding and flash floods on July 17, causing fatalities. According to the media, there were four fatalities and numerous injuries. Eleven settlements in Gulani and one community in Gujba have lost over 100 households. The key

bridge connecting several communities, including Gulani, Bara, Gagure, and Njibulwa, was severed. (ECHO, 2022).

According to the State Emergency Management Agency, flooding has affected 43,155 individuals in 26 Local Government Areas (LGA) throughout the BAY states since the start of the rainy season (SEMA). A total of 4,347 people are thought to have been displaced, with the elderly, women, and kids suffering the most. Schools are home to the majority of displaced individuals. According to partners' early needs assessments, Tonga and Fufore LGAs in Adamawa state and Gujba, Geidam, and Gulani LGA in Yobe state have been the most severely hit areas by the floods. According to the State Emergency Management Agency, flooding has affected 43,155 individuals in 26 Local Government Areas (LGA) throughout the BAY states since the start of the rainy season (SEMA). A total of 4,347 people are thought to have been displaced, with the elderly, women, and kids suffering the most. Schools are home to the majority of displaced individuals. According to partners' early needs assessments, Tonga and Fufore LGAs in Adamawa state and Gujba, Geidam, and Gulani LGA in Yobe state have been the most severely hit areas by the floods. (OCHA, 2022).

Jigawa State in northern Nigeria is still experiencing flooding, which has a greater humanitarian impact. At least 50 individuals have passed away in Jigawa since the start of the rainy season, according to reports from NEMA and the media in Nigeria. As a result of floods that have devastated numerous homes, buildings, farms, livestock, and properties, hundreds of households have been relocated to 11 temporary camps. Over most of Nigeria, including Jigawa State, moderate to heavy rainfall is predicted during August 23–25. (ECHO, 2022).

Media reports state that since the start of 2022, there have been 300 flood-related fatalities, 100,000 displaced persons, and 500,000 affected people nationwide. (ECHO, 2022).

According to the media (citing national authorities), as of October 18, there have been 603 fatalities, more than 2,400 injuries, approximately 1,303,000 displaced persons, and more than 2,504,000 affected people nationwide. With almost 700,000 people either relocated or affected, the Bayelsa State is particularly the hardest affected. The same sources also state that there are about 203,400 damaged houses, of which over 82,000 have been completely damaged or destroyed. (ECHO, 2022).

1.2 Statement of the Problem

A flood is an overflow of water that submerges or covers land; it is an overflow of a great body of water over land that is not usually submerged, (Akpejiori, 2017). It is a critical environmental problem and major hazard which continuously affects the effective functioning of urban environments, especially in the areas of infrastructure and service provision which are germane to sustainable livelihood (Klemas, 2015). Recent flood disasters in Benin City, Edo State, have recorded several lives lost, damaged properties, and residents of the areas affected are homeless. This project aims to assess the flooding in Benin City in order to find a suitable situation to address and prevent it from reoccurring.

In the Edo State area of Ikpoba-Okha, flooding is a major problem and occurs often during the rainy season, this is major as a result of several activities which include; heavy rainfall, the failure of man-made structures such as channels, blocked or poorly constructed drainages, building on flood plains, poor planning and land use. Factors suspected to be responsible for several floods in the area in percentage and the major causes of flooding in Ikpoba-Okha. These showed the causes of flooding to be the five main parameters in this region. These causes included; Heavy rainfall 40%, poorly constructed/lack of drains 31%, building on flood plains 11%, and poor planning/land use 18% (Goscence, 2009) Also, another observation in the percentage as well for major inconveniences/effects caused by flooding in

this region were also; Relocation of property 20%, abandonment of houses 38%, psychological fear 26%, and abandonment and relocation 16%. (Giuseppe, 2019)

1.3 Aim and Objectives

This project aims to use remotely sensed satellite technology to monitor flood problems affecting Ikpoba-Okha, with the following specific objectives:

- i. To use remotely sensed satellite technology to know the areas affected by flood in the study area in order to discover the area that has a high flood risk.
- ii. To examine the dominant environmental factors responsible for the flooding.
- iii. To produce a flood risk map of the study area.

1.4 Scope of the Study

The scope of the study was to analyze acquired data from sources after retrieving useful information from the geo-referenced map and images obtained from satellite imagery. These satellite imageries (Sentinel-2) were downloaded from USGS which was used in the creation of a flood risk map (DEM) as well as the Land Use/Cover map of the study area which highlighted areas prone to flood, the Rainfall of the study area was re-sampled and gridded to determine the annual mean rainfall in the study area. The study is limited to the study area, it takes no account of the geological aspect of the basement, and no engineering design is involved. The spatial resolution of the imageries was a determining factor in the accuracy of the final results, and climatic change may introduce certain errors, according to the limitations found in this work. The results are only relevant to the study area.

1.5 Justification of the Study

When carrying out planning and design in an area in its primary stage, note beforehand if the region is likely to be affected by flooding especially if the region is close to a water body. Knowing the details and information of the area would prevent any risk of flood disaster.

The knowledge of flood extent in Ikpoba-Okha could be used as a database for the monitoring of floods in the region.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 FLOODING

Flooding is defined as a violent dynamic phenomenon in which a river's discharge exceeds its water-carrying capacity, causing overtopping of banks and flooding of previously dry regions (Ehiorobo, 2017).

It is also defined by Giuseppe (2019) as the overflowing or eruption of a large amount of water over a terrain that is not normally submerged and is sometimes referred to as a flood (Giuseppe, 2019). Excess precipitation surpasses natural infiltration, evaporation, and probable runoff, resulting in the flooding of any region not ordinarily covered by water due to a sudden rise in the level of a river, lake, or sea.

2.1.1 Flood Characteristics

Characteristics of a flood can be easily known when the flood occurs. To know the best solution to solve floods, we should know the flood characteristics (what are the causes, the inundation, the area, height, how long it occurs, etc.) (Farid 2019). The characteristics of the flood are briefly discussed below.

- i. **Flood Frequency:** Flood frequency is the idea of a specific flood's likely frequency of occurrence (Duncan, 2005). Flood frequency data is frequently used to regulate land use and settlement in flood-prone locations. Estimates of flood frequency are especially significant in heavily populated metropolitan areas.
- ii. **Flood Intensity:** Flood intensity refers to the amount of damage a flood causes. The depth of inundation, volume of inundation, velocity of flow, and rate of rising of water

may all be used to describe it. The greater the depth of water, the greater its volume, velocity, and destructive potential. A rapid increase in water implies that individuals in the vicinity will have less time to prepare. (Mulia, 2019).

- iii. **Flood Duration:** The duration of a flood occurrence refers to how many times flooding occurs in a certain period (Mulia, 2019). This metric is critical because it aids in determining and determining the level of flood damage, particularly to individuals and communities (Bariweni, 2012)

2.1.2 Causes of Flooding in Nigeria

While climate change has resulted in more rain than in the past, increasing the incidence of flooding, Nigeria's flooding is mostly caused by humans and aggravated by human-nature interactions (Aderogba, 2012). Flooding in Nigeria is caused by human nature, which includes, but is not limited to Inadequate or non-existent Drainage systems, inadequate waste management, weak implementation of planning laws, uncontrolled urbanization, etc.

a. Inadequate or non-existing Drainage systems

This is a key human-caused factor in the floods in Nigeria (Ogundele, 2011) Most residential areas in Nigeria lack a drainage system and rely on natural drainage; nonetheless, it is typical for houses and other infrastructure to be built in such a way that these drainage channels are obstructed, resulting in floods during the rainy season (Nebugu 2014). Nigeria's expanding urbanization has resulted in a growing share of concrete ground surfaces. This indicates that there is no water percolation and that suitable drains are not in place to handle surface runoff (Adebayo J, 2011). Drainage solutions are urgently needed to address the problem of floods (Etuonovbe, 2011).

b. Inadequate waste management

One of the anthropogenic elements adding to and exacerbating Nigeria's already challenging flooding situation is improper/poor waste management (Ojo, 2017)

Various research (Eneji, 2017) have examined Nigerians' inadequate attitude toward trash disposal (Ojo, 2017). In Nigeria's densely populated metropolitan regions, drainage obstructions caused by inadequate sanitation standards are frequent. A high percentage of the populace engages in roadside dumping, canal dumping, and rainwater dumping. This leads to floods during the rainy season and creates obstruction as well as a contaminated environment (Andrew, 2012).

c. Weak implementation of planning laws

Nigeria's planning laws are of high quality; however, they are inadequately developed and implemented (Nnaemeka, 2016). Political intervention in work planning, understaffing, and a lack of working equipment are all problems that hinder effective planning and the planners' ability to carry out their responsibilities (Nnaemeka, 2016; Adeleye, 2018). Because of the loose implementation of planning rules, development projects on natural floodplains and storm water routes are authorized, causing floods and having negative consequences for the environment (Adaku, 2016). Most of the time, individuals took advantage of the loophole created by inefficient development regulation and built over allowed areas, even going so far as to construct over drainages in certain situations. The failure to apply the rules hurts attaining long-term urban development.

d. Uncontrolled urbanization

In both emerging and established nations, urbanization and floods are inextricably linked. Nigeria has seen and continues to experience significant rates of urbanization without an equivalent supply of urban infrastructure and facilities (Aderogba, 2012). Agricultural fields are also rapidly being converted to residential areas to meet housing demands, and development occurs without sufficient regulations and infrastructure in place, aggravating the flooding crisis (Metzger, 2018).

2.2 TYPES OF FLOODING

Floods occur in Nigeria in three main forms:

- a) River flooding
- b) Coastal flooding
- c) Urban flooding

2.2.1 River Flooding

River flooding occurs in the flood plains of the larger rivers, while sudden, short-lived flash. Floods are associated with rivers in inland areas where sudden heavy rain can change them into destructive torrents within a short period (Folorunsho, 2001).

2.2.2 Coastal Flooding

Coastal flooding is the inundation of normally dry land areas along the coast with seawater. Coastal flooding is a result of a combination of sea tidal surges, high winds, and barometric pressure (Anon., 2021). Also, Folorunsho (2001) defined coastal flood as a flood which occurs in the low-lying belt of mangrove and freshwater swamps along the coast.

2.2.3 Urban Flooding

Urban flooding is the main impact of meteorological and climatic change. It is considered a major and serious environmental problem confronting municipal authorities in developing countries. It is a critical environmental problem and major hazard which continuously affects the effective functioning of urban environments, especially in the areas of infrastructure and service provision, which are germane to a sustainable livelihood. When severe flooding occurs in areas occupied by humans, it causes loss of human life and property and serious disruption to the activities of large urban and rural communities. The economy is also severely affected by flooding as businesses may lose stock and patronage. Also, disruption of utilities and transport infrastructure can be adversely affected in a wider area. Flooding is

therefore a universal reality that cuts across every sphere of human society [Geoscience 2019].

Urban flood, on the other hand, occurs in towns, on flat or low-lying terrain, especially where little or no provisions have been made for surface drainage, or where existing drainage has been blocked with municipal waste, refuses and eroded soil sediments (Folorunsho 2001).

2.3 THE FLOODING REPORTED AROUND THE WORLD

The following types of flooding are given by Klemas et al. (2015): River flooding, coaster flooding, inland flooding, flashes flooding, and urban flooding.

- i. **River Flooding:** This form of flood happens when the water level rises above the riverbanks. This type of flooding can occur in any river or stream channel. Everything from little streams to the world's biggest rivers falls into this category. Excessive rain from tropical storm systems reaching landfall, as well as continuous thunderstorms, can all contribute to this sort of flood (Klemas, 2015).
- ii. **Coastal Flooding:** A coastal flood occurs when seawater inundates typically dry land regions near the coast. Coastal flooding is caused by a combination of strong winds, sea tidal waves, and barometric pressure. Storms at sea, such as tropical cyclones, tsunamis, and higher-than-average tides, are primarily responsible for these circumstances. (Klemas, 2015).
- iii. **Inland Flooding:** This sort of flood occurs inland. One of the main causes of inland floods is rainfall. Inland flooding may occur in two ways: as a consequence of consistent rainfall over several days or as a result of a brief and severe spell of rainfall. (Klemas et al., 2015) Inland flooding may also occur when waterways are obstructed by garbage, rubbish, and other material. Inland floods may be extremely upsetting since the water has nowhere to go as a result of the elements that generate the flooding. Paved

streets and roads, low-capacity drainage infrastructure, dense structures, and a lack of green space are all examples of these characteristics.

iv. **Flash flood:** The most well-known and devastating form of a flood is the flash flood. Within six hours of severe rainfall, and typically within three hours, this sort of flood occurs (or another cause) (Klemas 2015). The majority of flash floods occur when violent thunderstorms produce a large amount of rain in a short period (normally 6 hours or less). There are two main factors to consider when determining the likelihood of flash flooding, these are:

i. Rainfall duration

ii. Rainfall rate

Flash floods are extremely strong; they can overturn boulders, rip trees from the ground, and damage houses and bridges, among other things. They can occur with little or no notice.

v. **Urban Flood:** Urban floods occur in towns, on flat or low-lying terrain, particularly where little or no surface drainage has been built, or where existing drainage has been obstructed by municipal garbage, rejects, and degraded soil sediments. Folorunsho, (2001), (Ologunorisa, 2004).

Flooding has resulted in the loss of life (the worst effect of all), property damage, economic implications, the destruction of foods and livestock, and road damage, among other things. Floods may wreak havoc on structures, roads, and bridges, uproot trees, and wreak havoc on crops. NOAA/NWS (2005), states that mudslides can occur, posing a hazard to human life. Floods, regardless of the type, always have a detrimental impact; in addition to posing a physical threat, they also generate economic and societal issues as shown in figure 2.1.



Figure 2.1: Ikpoba-Okhas flooded region, (Akenzua 2020)

According to project research by Abdullah (2018), standard methods for documenting flood hydrological data frequently fail to relate to intense events. The goal of the study was to look at the damages caused by different land uses such as built-up areas, agricultural land, and flood heights, as well as the proportion of loss in each land use in different years. The research region for this investigation was the Naogaon District.

2.4 INTRODUCTION TO METHODS OF MONITORING FLOODS

2.4.1 Flood Probability

Probability in flood studies refers to determining the probability of occurrence of a flood event to calculate the design flood. There are different methods of determining flood probability. For this study, flood frequency analysis is undertaken which makes use of observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, and sleekness and recurrence intervals. Flood frequency analysis is used to estimate the flood quartiles that can occur in a given time interval and to know the peak flow expected over different periods at the location. This information is used by a

hydrologist civil engineer to determine the size of a hydraulic structure for controlling floods and is also used by urban planners and civil engineers to determine the best locations for infrastructures needed for the development of the area (Juliet, 2017).

2.4.2 Floodplain Delineation

Flood plain delineation is the process of determining inundation extent and depth by comparing river levels with ground surface elevations. The method consists of the following basic steps.

1. River stages are observed or water levels are simulated from surface water models at different points or locations along the river.
2. A topographic map is collected for use if available or may be prepared as required.
3. Water levels are marked on the topographic map.
4. Water levels are extended until impeded by higher elevation.
5. The contour lines are traced to delineate the floodplain
6. The flood extent maps are then manually prepared.

However, in recent times, the estimation of flooded areas is now undertaken using remote sensing (RS) techniques along with Geographic Information System (GIS) data. When flood plain is to be delineated by remote sensing techniques, it is necessary to have satellite imagery.

2.4.3 Flood Hazard Mapping

Flood hazard mapping for this study is achieved using remote sensing and GIS techniques. Remote sensing is used as a tool for providing an overview of the distribution of flood events and could be used to measure and analyze the extent to which the flood has occurred over the flooded area. This was achieved through the provision of spatial data such as high-resolution satellite imageries which are used in run-off analysis, flood forecasting and flood hazard mapping by the application of the Geospatial Information System (GIS) technology. This

technology combines satellite information and observation obtained from the ground to generate models of present and future occurrences of flood events. These models provide a measure of assessment of damages due to current and future flood events. Remote sensing technology along with GIS has become the key tool for flood monitoring in recent years. The central focus in this field revolves around the delineation of flood zones and the preparation of flood hazard and flood risk maps for vulnerable areas. Remote sensing techniques generate images, and land information such as slope; elevation and land cover data which are then manipulated in GIS environments to create databases with other measured parameters from the ground surface to analyze problems of interest and proffer solutions to such issues. Due to the high cost of imagery required for a study such as LIDAR which incorporates land cloud cover data in this part of the world, a low-resolution USGS/NASA SRTM DEM from the SRTM website with a spatial resolution of the GeoTiffs as 6000 x 6000 pixels was the best available option for generation of maps for the study.

In this case, remote sensing data was utilized in conjunction with a Geographic Information System (GIS), which has been a major tool for flood monitoring in recent years. Landsat 4-5 Thematic Mapper pictures were taken for the years 2004, 2007, and 2012, as well as Landsat 8 Operational Land Imager (OLI) and Thematic Infrared Sensor (TIRS) photos for the year 2017. Each year, photographs of the Naogon district on various dates (March and September) were captured Geographical Information System (GIS) and ERDAS envision software was used to evaluate the data. The investigation revealed the variety of land use changes in the four occurrence months from 2004 to 2017, which were dependent on this shift. The study also looked at the relationship between flood height and land usage.

Remote sensing uses a part or several parts of the electromagnetic spectrum, it records the electromagnetic energy reflected or emitted by the earth's surface. The amount of radiation

from an object (called radiance) is influenced by both the properties of the object and the radiation hitting the object (Aggarwal, 2019).

However, the method used in this project included SRTM DEM classification of water bodies in the study area based on the homogeneous characteristics of the data to show water level using ArcGIS software, satellite imagery (Sentinel-2) was then used to extract water bodies and the water index was then calculated using the various bands of the Sentinel-2 data, the integration of GIS and Remote Sensing resulted in the creation of a DEM, and the study area's flood threat.

A project study was carried out by Akpejiori (2017) to analyze flood risk potential in Agenebode, Edo State, Nigeria. This was accomplished by conducting a flood frequency study on discharge data obtained from the River Niger at Onitsha between 1960 and 2006, using Gumbel probability distribution models to get the best appropriate discharge forecast for various return periods.

2.5 EFFECTS OF FLOODING

Flooding has resulted in the loss of human lives, and output, and, in most cases, has a negative influence on the nation's economy (Ehiorobo, 2017). Several studies have also indicated that flooding disasters can expose sufferers to a variety of health-related issues, as most disorders fall into several categories (Foudi, 2017).

Given that rivers provide food, freshwater, and rich terrain for farming, it is not a surprise that they have played a significant role in human history. Water may be a devastating force even though it is necessary for life. River flooding can have disastrous consequences (Tyson, 2022).

One of the most frequent natural disasters is flooding, and it frequently has terrible consequences. One of the worst flooding incidents ever was the Central China Flood of 1931, for instance. Numerous million people may have perished when the banks of the Yangtze and

Huai Rivers were breached. The aftermath was disastrous; fast-spreading watery illnesses like dysentery and cholera put those who survived in danger of famine (Tyson, 2022). Flooding can have a high human cost, but it also has significant consequences on the natural world, some of which are positive. In reality, seasonal flooding is a key driver of ecological processes in several ecosystems (Tyson, 2022).

2.5.1 Floods Can Harm Wildlife

Flooding can harm wildlife by causing drowning, the spread of diseases, and the ruin of habitats. Hundreds of animals perished in floods that engulfed Kaziranga National Park in the Indian state of Assam in 2012, many of them endangered one-horned rhinos (*Rhinoceros unicornis*). Even aquatic life may be harmed by unforeseen floods. For instance, fish may be uprooted and their nests may be destroyed (Tyson, 2022).

2.5.2 Floods Cause Sedimentation and Erosion

By eroding riverbanks and forcing them to collapse, for example, floodwater can also change the terrain. Floodwater suspends silt in the water as it drags debris from the eroding banks, which can deteriorate the water's quality and cause toxic algae blooms. In a process known as sedimentation, suspended material eventually settles out of the water, clogging riverbeds and streams, suffocating aquatic species, and destroying habitats. Ecosystems that have already suffered degradation or significant alteration are more adversely affected by erosion and sedimentation (Tyson, 2022).

2.5.3 Flood Carry Contamination

Pollutants including sewage, industrial chemicals, garbage, and pesticides used on farms can contaminate floodwater. Floodwater that has been contaminated can damage the ocean's water quality and upset delicate ecosystems like coral reefs. In February 2019, after being flooded by contaminated floodwater, marine biologists feared for the survival of the Great Barrier Reef off the coast of Queensland, an Australian state (Tyson, 2022).

2.5.4 Floods Spread Diseases

Infectious illness outbreaks linked to weather are most frequently caused by floods. Flooding incidents raise the potential for the development of cholera and hepatitis A, two watery illnesses. Floodwater that has receded may leave behind pools of stagnant water that are ideal mosquito breeding grounds and can spread diseases like malaria. Events like floods also cause an increase in some zoonoses like leptospirosis (Tyson, 2022).

Numerous negative effects are brought on when places used for socioeconomic activity are flooded. The severity of negative effects is influenced by the population's and activities' susceptibility to floods as well as their frequency, intensity, and extent. Here are a few of these elements: Loss of lives and property, Loss of livelihoods, Decreased purchasing and production power, Mass migration, Psychosocial effects, Hindering economic growth and development and Political implications (Hwirin, 2013).

2.5.5 Loss of Lives and Property

The immediate effects of floods include loss of life, property damage, crop and livestock loss, infrastructure facility failure, and worsening of health due to waterborne infections. More people die in flash floods than in riverine floods due to the short or nonexistent warning period (Hwirin, 2013).

The most serious result of floods is death. Flooding is the leading cause of death from extreme weather. Thousands of people have died as a result of floods throughout history (Chaudhary, 2000).

An automobile can be washed away in just two feet of flood water, but flooding can also result in significant property loss. Flooding damages buildings by blowing out windows, washing doors away, corroding walls, foundations, and dumping debris into infrastructure at a rapid rate (Chaudhary, 2000).

2.5.6 Loss of livelihoods

Economic activity stops as a result of damaged and disturbed communication linkages and infrastructure, including power plants, highways, and bridges, which causes disruption and the dysfunction of daily life for a considerable amount of time after the floods. In a similar vein, direct damage to production assets, whether in industry or agriculture, can stifle regular activity and result in the loss of livelihoods. Even in nearby non-flooded areas, the consequences of the loss of livelihoods may be seen in economic and commercial activity (Dr Hwirin, 2013).

2.5.7 Decreased Purchasing and Production Power

Long-term effects of infrastructure damage include interruptions in clean water and energy, transportation, communication, education, and health care. Communities residing in the region become more vulnerable as a result of lost livelihoods, less buying power, and decreased land value in the flood lowlands. The extra expense of restoration, moving people, and removing property from flood-affected regions might divert the money needed to keep production going (Hwirin, 2013).

2.5.8 Mass Migration

Frequent floods can cause population displacement or mass migration by causing a loss of livelihoods, output, and other long-term economic repercussions. Urban congestion is a result of migration to established metropolitan regions. These immigrants increase the number of urban poor people who must live in low-lying areas in danger of flooding or other hazards. Selective worker emigration can occasionally lead to challenging societal issues (Hwirin, 2013).

2.5.9 Psychosocial Effects

The severe psychosocial repercussions of flooding can leave individuals and their families traumatized for a very long time. Losing a loved one may have lasting effects, especially on children. Continued stress can be brought on by being uprooted from one's home, losing

assets and means of support, and experiencing disruptions in social and professional affairs. Overcoming this stress and the resulting losses might have long-lasting psychological effects (Hwirin, 2013).

Flooding can cause victims to experience long-term trauma. The loss of loved ones or houses may be devastating to children's emotions (Anon, 2021). Displacement from one's home and loss of life can result in long-term stress and psychological effects.

2.5.10 Hindering Economic Growth and Development

The massive expense of rescue and recovery efforts might have a detrimental impact on investments in the region's infrastructure and other development initiatives, and in certain cases, it might even be sufficient to completely devastate the area's already precarious economy. Long-term investments may be discouraged in a region due to frequent floods by the public and private sectors. Unemployment, skilled labour migration, and inflation may have a detrimental effect on the economic progress of an area. Resources being lost might lead to costlier goods and services, which would delay development activities (Hwirin, 2013). Flooding may have a disastrous economic impact on a town. This is due to damage and interruption to communication towers, power plants, highways, and bridges, among other things. This might put a halt to commercial activity in a given region (Anon, 2021). Because of the enormous cost of relief and recovery connected with floods, floods stymie economic progress and development.

2.5.11 Political Implications

The people may become dissatisfied with the authorities or lose faith in the state and federal governments if relief efforts are not handled effectively after significant flood occurrences. The absence of growth in flood-prone areas may result in social injustice and possibly civil upheaval, endangering the peace and stability of the area (Hwirin, 2013).

Flooding affects humans and the environment in many ways. Flooding has a range of impacts on humans, including:

- people can be injured or killed by flooding
- floodwater is often contaminated with sewage, which can lead to illness and affect clean drinking water
- power supplies can be disrupted
- businesses can be forced to shut down
- services such as hospitals and schools can close
- transport networks can be affected, such as flood damage to bridges, railways and roads
- homes and properties can be flooded
- People may have to move out of their properties until flood damage is repaired.

Flooding has a range of impacts on the environment, including:

- i. wildlife habitats can be destroyed by floodwater
- ii. contaminated floodwater can pollute rivers and habitats
- iii. silt and sediment can destroy crops on farms
- iv. river banks and natural levels can be eliminated as rivers reach bank-full capacity
- v. rivers can be widened, and deposition can increase downstream
- vi. trees can be uprooted by high-velocity water flow
- vii. plants that survive the initial flood may die due to being inundated with water

2.6 RECENT FLOODING IN NIGERIA

Several areas of Nigeria have witnessed flooding, which is quickly turning into an annual occurrence and has resulted in the loss of land, lives, and livelihoods. Despite historically challenging events, the present flood seems to be the worst the nation has seen in the previous ten years. Extreme rainfall and water being released from the Lagdo Dam in Cameroon have

caused significant flooding in largely South-Southern regions for weeks. This exercise took place till November 18, (Dengiyefa, 2022).

Since early October, the government has been measuring the losses caused by the current spate of floods. Almost 2.5 million people have been impacted, out of whom 1.3 million have been forced to relocate, 2,407 have been wounded, and 603 have died in 25 states that have been particularly badly hit, (Dengiyefa, 2022).

Flooding in Nigeria has thus far been minimized in terms of its socio-political implications and, if at all, highlighted in terms of the financial consequences as an isolated environmental concern brought on by climate change. Flooding's multifaceted repercussions, which go beyond just making economic problems worse, had the potential to influence Nigeria's elections in 2023, (Dengiyefa, 2022).

2.6.1 The Implication of the Floods on the 2023 Elections

With the existing security issues, analysts, academics, and policy experts have raised worry over the Independent National Electoral Commission's (INEC) arduous task of conducting the elections. Few people, however, would have taken into account the role that floods played in the successful conduct of the election. Around 300 towns in Bayelsa State, including the community of former president Goodluck Jonathan, have reported incidences of internal displacement affecting close to a million residents. Also, vital infrastructure has been lost, including telecommunications networks, hospitals, and bridges, (Dengiyefa, October 2022).

The crucial East-West Road has also been taken over, leaving the state effectively shut off from the rest of the nation. Anambra states that a third of its state is underwater, and Kogi in the north-central has also been impacted by the flooding, so Bayelsa is not alone. Each of these states is led by a leader from a different political party, demonstrating how this catastrophe transcends current politicking, (Dengiyefa, 2022).

Notwithstanding the damage caused by the floods, it is evident that there is hope that things will improve in time for the elections. On Sunday, President Buhari travelled to South Korea for a summit, and the management of INEC has not disclosed any plans to alter election preparations in response to the flooding. Yet this would be disastrous for several reasons.

First off, the movement of crucial electoral materials is a major factor in the conduct of elections. The failure to deliver election materials on time to voting locations has previously been attributed to INEC. This occasionally breeds mistrust because some voters assume that the elections have already been manipulated, (Dengiyefa, 2022).

In most cases, INEC has attributed delivery delays to inadequate transportation systems. Mahmood Yakubu, the chair of INEC, mentioned this as one of their biggest difficulties at a recent session hosted by the CDD and the Open Society Initiative for West Africa that focused on emerging issues influencing the next elections. This is because some regions of the nation remain entirely inaccessible and are only accessible by motorbike or boat. The devastation of road infrastructure by the floods might impede planning, even the hiring of ad hoc employees, as well as the efficient training and deployment of law enforcement personnel, especially in coastal states, the South-South and close to the Rivers Benue and Niger, (Dengiyefa, 2022).

The second issue, which is perhaps more pressing, is the challenge of successfully issuing Permanent Voters Cards (PVC) to citizens in flood-affected areas. The duty of INEC to make PVCs available will be made more difficult by the loss of some facilities and the relocation of communities. It might also be a problem if voters blame the flooding for the loss of their PVCs and if many people accidentally lose their right to vote. Even the acknowledged legitimacy of the elected authorities might make the conclusion challenging. Lastly, the socio-political climate in which these surveys will be conducted is likely to be impacted by the floods. Given the grim fact that 76,168 hectares of agriculture have been largely

destroyed and 70,566 hectares have been fully devastated, there is a well-established association between poverty and vote buying that might be made worse. According to the Federal Ministry of Humanitarian Affairs, Disaster Management, and Social Development, 90,000 dwellings have been damaged by floods in some way. This will probably affect how politicians appeal to the voters and if they utilize financial promises to win their support.

Flooding in Nigeria is an increasingly serious problem, for example, the release of excess water from the Lagdo Dam in Cameroon, which often contributes to flooding in Nigeria, was supposed to be contained by a dam, the Dasin Hausa Dam in Adamawa State, north-east Nigeria. But after more than 40 years the dam still isn't complete. Many of the rivers in Nigeria are poorly managed and regulated. Siltation of major rivers such as the River Niger, as well as the removal of vegetation from river banks and wetlands for agricultural purposes, is all outcomes of poor water resources management which have also contributed to flooding.

2.7 METHODS AND TECHNIQUES FOR MONITORING FLOODING

Flood Probability, Flood plain delineation, Flood Hazard Mapping, land use/land cover and Rainfall Pattern

2.7.1 Flood Probability

Probability in flood studies refers to determining the probability of occurrence of a flood event to calculate the design flood. There are different methods of determining flood probability. For this study, flood frequency analysis is undertaken which makes use of observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, and sleekness and recurrence intervals. Flood frequency analysis is used to estimate the flood quartiles that can occur in a given time interval and to know the peak flow expected over different periods at the location. This information is used by a hydrologist civil engineer to determine the size of a hydraulic structure for controlling

floods and is also used by urban planners and civil engineers to determine the best locations for infrastructures needed for the development of the area (Juliet Akpejiori).

Flood probability can be calculated using the Weibull formula

$$TR = N + 1/M \quad (2.1)$$

Where n = number of recorded years for the data, m = rank of each year obtained arranging the data in descending order of magnitude with the highest value getting a value of 1, the next larger getting 2 and so on. The general equation used for deriving expected discharges Q_T for the different return periods is:

$$Q_T = Q + K\sigma \quad (2.2)$$

Where Q is the mean of the discharge data, K is the frequency factor corresponding to each return period for the different distributions and σ is the standard deviation for the discharge

data calculated from $\sigma = \sqrt{\frac{\sum(q-q)^2}{n-1}}$

2.7.2 Flood Plain Delineation

Flood plain delineation is the process of determining inundation extent and depth by comparing river levels with ground surface elevations. The method consists of the following basic steps.

1. River stages are observed or water levels are simulated from surface water models at different points or locations along the river.
2. A topographic map is collected for use if available or may be prepared as required.
3. Water levels are marked on the topographic map.
4. Water levels are extended until impeded by higher elevation
5. The contour lines are traced to delineate the floodplain.
6. The flood extent maps are then manually prepared.

However, in recent times, the estimation of flooded areas is now undertaken using remote sensing (RS) techniques along with Geographic Information System (GIS) data. When flood

plain is to be delineated by remote sensing techniques, it is necessary to have satellite imagery, (Aggarwal, 2019).

2.8 FLOOD HAZARD MAPPING

Flood hazard mapping for this study is achieved using remote sensing and GIS techniques. Remote sensing is used as a tool for providing an overview of the distribution of flood events and could be used to measure and analyze the extent to which the flood has occurred over the flooded area. This was achieved through the provision of spatial data such as high-resolution satellite imageries which are used in run-off analysis, flood forecasting and flood hazard mapping by the application of the Geospatial Information System (GIS) technology.

This technology combines satellite information and observation obtained from the ground to generate models of present and future occurrences of flood events. These models provide a measure of assessment of damages due to current and future flood events. Remote sensing technology along with GIS has become the key tool for flood monitoring in recent years. The central focus in this field revolves around the delineation of flood zones and the preparation of flood hazard and flood risk maps for vulnerable areas. Remote sensing techniques generate images, and land information such as slope elevation and land cover data which are then manipulated in GIS environments to create databases with other measured parameters from the ground surface to analyze problems of interest and proffer solutions to such issues. Due to the high cost of imagery required for a study such as LIDAR which incorporates land cloud cover data in this part of the world, a low-resolution USGS/NASA SRTM DEM from the SRTM website with spatial resolution of the GeoTiffs as 6000 x 6000 pixels was the best available option for generation of maps, (Aggarwal, 2019).

In this case, remote sensing data was utilized in conjunction with a Geographic Information System (GIS), which has been a major tool for flood monitoring. The study also looked at the relationship between flood height and land usage.

Remote sensing uses a part or several parts of the electromagnetic spectrum, it records the electromagnetic energy reflected or emitted by the earth's surface. The amount of radiation from an object (called radiance) is influenced by both the properties of the object and the radiation hitting the object (Aggarwal, 2019).

However, the method used in this project included SRTM DEM classification of water bodies in the study area based on the homogeneous characteristics of the data to show water level using ArcGIS software, satellite imagery (Sentinel-2) was then used to extract water bodies and the water index was then calculated using the various bands of the Sentinel-2 data, the integration of GIS and Remote Sensing resulted in the creation of a DEM, and the study area's flood threat.

A project study was carried out by Akpejori, (2017) to analyze flood risk potential in Ikpoba-Okha, Edo State, Nigeria.

2.8.1 Land Use/Land Cover

The phrases "land use" and "land cover" are closely related but distinct. Land cover describes the physical elements that, at a certain area, cover the Earth's surface, such as ice, bare ground, grassland, or man-made surfaces like asphalt or concrete. The term "land use" describes the economic purpose for which a piece of land is used, with "nature reserve" serving as an example. Consequently, the same type of land cover, such as enhanced grassland, might be utilized for both grazing cattle and pleasure, such as a golf course (i.e. agriculture). Classes of land parcels are commonly used to construct land use and land cover map layers. They are therefore a type of nominal or categorical data in which each land parcel has a label indicating the class to which it belongs. The land use/cover classes cannot be used to rank or arrange the parcels. The most frequent method for measuring land cover is remote sensing, while ground surveys are sometimes occasionally used. Surveys of land

ownership are increasingly frequently used to measure land usage. An agricultural census is one of the main methods used in many nations to gather data on land usage, (Barrett, 2001).

It's frequently a minimum mappable unit for both land use and land cover data. This is typically limited from a remote sensing standpoint by the source imagery selection. However, unless extremely complex super-resolution mapping techniques (Tatem, 2002) are utilized to analyze the images, imagery from the Spot panchromatic sensor can only be used to distinguish land cover patches that are bigger than 10 by 10 meters. Similar to this, the minimum mappable unit will depend on the scale of a land use/cover product. The degree of detail is adequate for the intended scale of usage since, at finer scales (such as 1: 200,000), tiny yet nearby areas of comparable land use/cover may be melded together through a process called map generalization. One tool that may be used to manage the amount of information in such a map so that it is suitable for a certain intended scale of usage is the ArcGIS tool "aggregate polygons". As a result, heterogeneous classes are often required to characterize patches of land that are composed of several small-scale patches of land that are too tiny to map (e.g. cropland with woodland). Land usage is subject to a similar restriction. Several agricultural censuses have a minimum amount of land under ownership, below which landowners are exempt from submitting a census form, (Barrett, 2001).

2.8. Rainfall Pattern

The study of the rainfall pattern is important because it is the remote cause of flooding in this area. Rainfall patterns must be adequately studied as this is the main cause of flooding especially in this part of the world. The rainfall data used for this project was that of Auchi, which is an adjoining city to the study area, (about 47km from the study area and is located in the same watershed as Agenebode) obtained from the Nigerian Meteorological Agency spanning 28 years from the year 1983 to 2019. The total rainfall volumes for each month of the year were obtained for the period and these were plotted

with Microsoft Excel spreadsheet application. The rainfall pattern is such that it peaks in May and September. The driest periods are at the beginning and end of the year that is October to December and January to April, (Barrett, 2001).

2.9 FLOOD RISK MANAGEMENT

Flood risk management (FRM) aims to reduce the human and socio-economic losses caused by flooding and is part of the larger field of risk management. Flood risk management analyzes the relationships between physical systems and socio-economic environments through flood risk assessment and tries to create understanding and action about the risks posed by flooding. The relationships cover a wide range of topics, from drivers and natural processes to models and socio-economic consequences.

This relationship examines management methods which include a wide range of flood management methods including but not limited to flood mapping and physical implication measures. FRM looks at how to reduce flood risk and how to appropriately manage risks that are associated with flooding. Flood risk management includes mitigating and preparing for flooding disasters, analyzing risk, and providing a risk analysis system to mitigate the negative impacts caused by flooding, (Erich, 2002).

Flooding and flood risk are especially important with more extreme weather and sea level rise caused by climate change as more areas will be affected by flood risk. There have been numerous flood incidents around the world which have caused devastating damage to infrastructure, the natural environment and human life. Flood risks can be defined as the risk that floods pose to individuals, property and the natural landscape based on specific hazards and vulnerabilities. The extent of flood risks can impact the types of mitigation strategies required and implemented (Erich, 2002).

Floods can have devastating impacts on human societies. Flooding events worldwide are increasing in frequency and severity, leading to increasing costs to societies.

Economic, social and natural environmental damages are common factors that are impacted by flooding events and the impacts that flooding has on these areas can be catastrophic.

As mentioned, the economic impacts caused by flooding can be severe. A large amount of the world's population lives near major coastlines, while many major cities and agricultural areas are located near floodplains. There is a significant risk for increased coastal and fluvial flooding due to changing climatic conditions. Every year flooding causes countries billions of dollars' worth of damage that threatens the livelihood of individuals. As a result, there are also significant socio-economic threats to vulnerable populations around the world from flooding, (Erich, 2002).

2.9.1 Management Methods

Flood risk management methods help reduce the risk of human and socio-economic losses caused by flooding and span many different disciplines. Management of the risks associated with flooding can decrease the costs incurred by governmental bodies, marginalized communities, individuals, and property.

Flood risk management strategy diversification is needed to ensure that management strategies cover several different scenarios and ensure best practices. The diversification of the flood risk management baseline framework can be used to help guide governing bodies to make decisions based on expert advice and common terms to ensure that strategies can be understood across multiple disciplines.

Flood risk management helps to decrease the negative economic, social, and physical consequences of flooding events. FRM involves several steps and it can occur before, during, or after flooding events. FRM examines five stages; how to prevent floods, the best defenses against flooding, the best way to mitigate the negative consequences of flooding, how to prepare for flooding events, and how to recover after a flooding event. By examining these

four different factors, governing agencies can evaluate risk management at different stages of flooding events (Erich, 2002).

The factors listed by Erich 2002 are flood mapping, Stakeholder Engagement, Flood modeling and Implementation Measures.

2.9.2 Flood Mapping

Flood mapping is a tool used by governments and policymakers to delineate the borders of potential flooding events, allowing educated decisions to prevent extreme flooding events. Flood maps are useful to create documentation that allows policymakers to make informed decisions about flood hazards. Flood mapping also provides conceptual models to both the public and private sectors with information about flooding hazards. Flood mapping has been criticized in many areas around the world, due to the absence of public accessibility, technical writing and data, and lack of easy-to-understand information. However, revived attention towards flood mapping has renewed the interest in enhancing current flood mapping for use as a flood risk management method, (Erich, 2002).

2.9.3 Flood Modeling

Flood modeling is a tool used to model flood hazards and their effects on humans and the physical environment. Flood modeling takes into consideration how flood hazards, external and internal processes and factors, and the main drivers of floods interact with each other. Flood modelling combines factors such as terrain, hydrology, and urban topography to reproduce the evolution of a flood to identify the different levels of flooding risks associated with each element exposed. The modelling can be carried out using hydraulic models, conceptual models, or geomorphic methods. Nowadays, there is growing attention also to the production of maps obtained with remote sensing. Flood modelling helps determine building development practices and hazard mitigation methods that reduce the risks associated with flooding (Erich, 2002).

2.9.4 Stakeholder Engagement

Stakeholder engagement is a useful tool for flood risk management that allows enhanced public engagement for agreements to be reached on policy discussions. Different management considerations can be taken into account including emergency management and disaster risk reduction goals, interactions of land-use planning with the integration of flood risks and required policies. In flood management, stakeholder engagement is seen as an important way to achieve greater cohesion and consensus. Integrating stakeholder engagement into flood management often provides a more complex analysis of the situation; this generally adds more demand to determining collective solutions and increases the time it takes to determine solutions (Erich, 2002).

2.9.5 Implementation Measures

Flood risk management includes the implementation of flood mitigation measures to reduce the physical impacts of floods. These measures can exist as precautionary measures based on an assessment of flood risk, as measures that are implemented before and during flooding events, or as measures implemented after a flooding event.

Precautionary measures include the implementation of flood water barriers, installing protective and/ or resilient technologies and materials in properties that are prone to flooding, regulations for building in flood-prone areas, flood warning systems, etc.

Measures such as the implementation of dikes can/should be constructed in countries or areas with low-lying landscapes following extreme flooding risk due to the country's low-lying landscapes. Other flood risk management strategies include flood-proof buildings, increased water storage capacity in reservoirs, and the construction of dams and embankments. Flood mitigation methods can also involve policy that reduces the number of urban structures built around floodplains. This policy helps to reduce the amount of mitigation needed to protect humans and buildings from flooding events. Following the occurrence of flooding events,

implementation measures such as rebuilding plans and insurance can be structured into flood risk management plans, (Erich, 2002).

2.10 REMOTE SENSING

The collecting and analysis of data or information about an object, location, or event without coming into direct touch with the thing or terrain are referred to as remote sensing (Sanderson 2014). Artificial and Satellite platforms are widely used for remote sensing of the globe, its natural riches, and ongoing activities. The development and deployment of manned and unmanned Satellites have improved the gathering of remotely sensed data and have provided a low-cost method of obtaining data/information across a vast region.

According to Jeyaseelan, (2017), the use of Earth Observation Satellites, which include both geostationary and polar orbit satellites. These satellites provide comprehensive, synoptic, and multi-temporal coverage of large areas in real-time and at frequent intervals, and it had become valuable for continuous monitoring of atmospheric and surface conditions, such as drought and flood-related parameters Geostationary satellites that offer continuous and synoptic weather observations, including cyclone monitoring, over broad regions.

Advances in remote sensing technology and Geographic Information Systems (GIS) have aided in the real-time monitoring, early warning, and rapid damage assessment of both drought and flood catastrophes throughout the world, particularly in the study region. Flood monitoring will be done using remote sensing technology by downloading optical satellite imagery from the study area, and forecasting flood risk by acquiring/generating a Digital Elevation Model (DEM) of the study area, which would aid in the creation of an early warning system for future flood events (Jeyaseelan, 2017).

Remote sensing's ability to detect and monitor land surfaces and the environment has substantially increased in recent years and remotely sensed data will be an important instrument in natural resource management. When solar radiation reaches the Earth's surface,

part of it is absorbed in specified wavelengths, while the remainder is reflected by the surface material. The only exceptions to this rule are if a body's surface is a perfect reflector or if it is a real black body. As the visible form of the electromagnetic wavelength was the initial manner of gathering distant sensed data, remote sensing entails acquiring data through electromagnetic (EM) wavelengths. However, technology has permitted the acquisition of data from other wavelengths.

The electromagnetic spectrum is a continuous range of electromagnetic radiation that includes visible light and extends from gamma rays (highest frequency, shortest wavelength) to radio waves (lowest frequency, longest wavelength) (Jeyaseelan 2017).

The electromagnetic spectrum is separated into seven distinct regions: gamma rays, X-rays, UV, visible light, infrared, microwaves, and radio waves are all examples of electromagnetic radiation.

The property we characterize as the colour of an item in the visible portion of the electromagnetic spectrum is the visible light that is not absorbed by that object as shown in figure 2.2 (Jeyaseelan 2017).

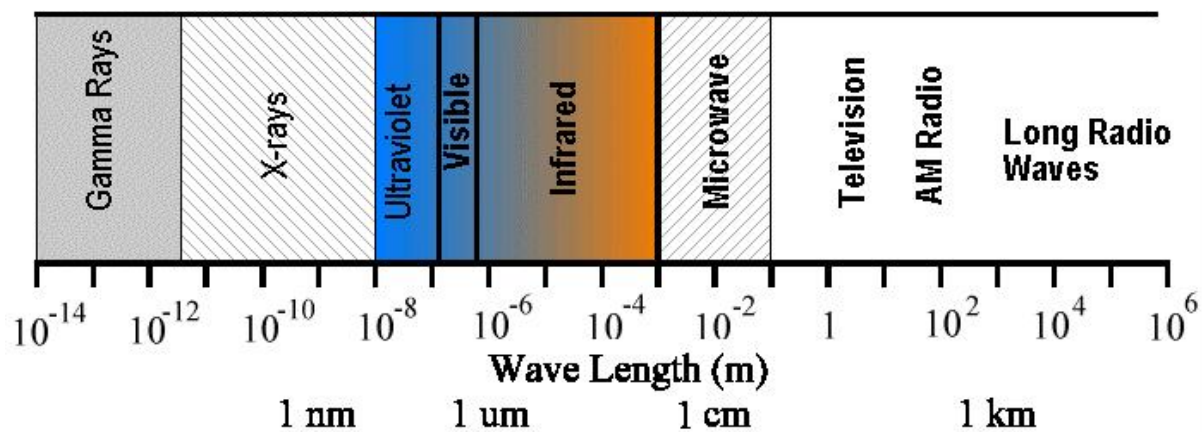


Figure 2.2: Electromagnetic wavelength diagram (Sanderson, 2014)

A detector monitors the electromagnetic radiation reflected from the Earth's surface materials in remote sensing (Sanderson, 2014). These observations can assist in distinguishing between

different types of land cover, soil, water, and plant, which all have distinct reflectance and absorption patterns at different wavelengths.

This electromagnetic radiation is measured and recorded by remote sensing sensors. These sensors are divided into two categories: passive sensors and active sensors. The standard photographic camera is an example of a passive sensor since it is powered by an external source of energy, generally the sun. A radar cannon, for example, is an active sensor with its source of energy. These passive and active sensors give out impulses and measure how much is reflected. By detecting solar radiation reflected from targets on the ground, remote sensing uses visible, near-infrared, and short-wave infrared sensors to create images of the Earth's surface (Sanderson, 2014).

Different materials reflect and absorb differently at different wavelengths, allowing the objects to be distinguished in remotely sensed pictures based on their spectral reflectance fingerprints as revealed in figure 2.3,



Figure 2.3: Remote sensing operation (Source: Hamakareem, 2019)

The measuring of energy in various areas of the electromagnetic spectrum is an element of remote sensing (EM). The visible light reflected and emitted infrared, and microwave ranges are the main areas of interest in satellite sensing. The spectral bands in which these radiations

are measured are known as spectral bands (Sanderson, 2014). The distance or distinct spacing between the electromagnetic spectrum's spectral bands is called a spectral band. The electromagnetic radiation reflected from the Earth's surface materials is measured by a detector.

These measurements can aid in the identification of the type of land cover. Over different wavelengths, the reflectance and absorption patterns of soil, water, and vegetation are different. The energy source (mostly the sun), radiation and environment, contact with the target, energy recording by the sensor, transmission, receipt, processing, interpretation and analysis, and application are all components of remote sensing.

The ground area observed for the sensing device's instantaneous field of view (IFOV) is the spatial resolution. The ground surface area that makes up one pixel in a satellite picture is also known as spatial resolution. The spatial resolution of the sentinel-2A varies between 10 and 60 meters, while the ground resolution of weather satellite sensors is frequently greater than a square kilometer.

The number and breadth of spectral bands in the sensing device determine the spectral resolution of a sensor system for remote sensing. A sensor with only one band that senses visible light is the simplest kind of spectral resolution. A picture captured by this sensor would resemble black-and-white photos taken by an airplane. A sensor in the visible area of the electromagnetic spectrum with three spectral bands would capture data similar to that of the human system.

Sentinel-2's multispectral picture spans thirteen spectral bands (443–2190nm) with a 290km sweep width. Four visible and near-infrared bands with a spatial resolution of 10m, six red edge and shortwave infrared bands with a spatial resolution of 20m, and three atmospheric correction bands with a spatial resolution of 60m are among the bands, (Sanderson, 2014).

2.10.1 Flood Monitoring Using Remote Sensing

This is critical for giving reliable data or information that covers a large region with many repeated observations. Remote sensing data is highly needed to effectively monitor flood occurrences (Cao, 2021).

According to (Muhammed, 2020), project work was carried out that included the use of remote sensing technologies, which included satellite images (sentinel-2) and SRTM data in flood mapping and modelling. Using Sentinel 2 MSI, the flood event of November 2019 was mapped and compared to the typical water level of the River Benue and the nearby Lakes Gerio and Njuwa. The flood event enveloped the two lakes and spread into the riverine marsh, encompassing about 450 per cent of the area covered by typical water conditions, according to the findings. Based on simulations, a flood event at 157 meters above sea level can perfectly match the November 2019 flood, extending and filling the whole wetland. This discovery was crucial in estimating inundation rates via forecasting future episodes. The simulated results could also serve as base data for engineering-based hydrologic flood models such as Hydrologic Engineering Centre - Hydrologic Modeling System (HEC-HMS) and Hydrologic Engineering Centre - River Analysis System (HEC-RAS). As a result of his project, he thereby recommended that high-resolution DEM would be required to enhance the accuracy of floods.

However, because of the limitation of revisiting each earth observation satellite, using multiple-sensor and multi-temporal earth observation satellite imageries will lead us to more frequent update flood situations than using only one earth observation satellite data. In general, two sets of remotely sensed data are necessary for flood mapping: one set gathered before the flood event and the other received during the flood event (Wang, 2002). A reference photograph is normally taken before the flood. These data may be used to determine flood boundaries and map inundation zones. To detect changes in surface water

extent and collect hydrologic information, field data can be combined with remote sensing readings from aero-planes or satellites.

Satellite imageries were used by (Pakorn, 2003) for mapping and monitoring flood-inundated regions, flood damage assessment, flood hazard zoning, and post-flood survey of river configuration and protection measures. By combining satellite data with other up-to-date spatial and non-spatial data, flood zones might be forecasted ahead of time. Radarsat1 and Landsat-7 data were two instances of satellite data applications employed for flood catastrophe prevention throughout the research, which was presented and addressed in the article. The findings show that satellite data can detect and provide information on the status, flooding time, border, and flood damage. For full flood mitigation planning, other geoinformatic data such as topographic elevation and hydrological data have to be linked. During this study and in the future, ground-truthing of data from the watershed region, such as water level, velocity, drainage pattern, and direction, was also valuable for flood forecasting.

Remote sensing flood monitoring is the use of sensor equipment to analyze flood assessment and detection. From image processing to hydrologic monitoring, a comprehensive approach to efficient and precise flooding necessitates a diverse set of skills. These sensors are electromagnetic energy measuring and recording devices. In coastal areas, the availability of multi-temporal satellite data allows monitoring of flooding over large areas. Aerial reconnaissance has been quite efficient and effective in determining the spatial extent of coastal and river flooding in detail for relatively small areas (Klemas, 2015; Raclot, 2002; Hoyos, 2004).

Although flood monitoring can be done using remote sensing from the global scale to the storm scale, it is most commonly done at the storm scale using hydrodynamic models to monitor the intensity, movement, and propagation of the precipitation system to determine

how much, when, and where heavy precipitation will fall in the next zero to three hours (called NOWCASTING). (MUTSO, 2011) Clouds have hampered satellite optical flood observations, resulting in a lack of near real-time data collecting. However, even in the presence of dense cloud cover, synthetic aperture radar (SAR) can maintain constant surveillance of the earth's surface. Hydrologic models are used to analyze and occasionally predict flood danger in flood forecasting. Land use, soil type, soil moisture, stream/river base flow, rainfall amount/intensity, and digital elevation model (DEM) data are all included in this model. (MUTSO, 2011) This forecast of a probable flood event can assist emergency managers and authorities in managing and developing contingency plans long ahead of a real flood event, allowing for a more efficient and successful response. Flood forecasts may be given over an area that displays the DEM obtained by remote sensing technology, which is used to guide precipitation and stream flow data. Remote sensing for flood monitoring has aided in the creation of DEM data and the definition of the research area, particularly when it comes to updating DEM data. Because Digital Elevation Models help to clearly illustrate areas/regions that are prone to flooding based on elevations, they can be used to advise communities/local authorities on the effects in affected areas as well as determine whether or not to carry out any activities required in the study area such as farming, building, and so on. Flood risk management plays an important part in flood monitoring; it is a key activity aimed at evaluating methods for decreasing, but not necessarily eliminating the total risk; this is because flood risk cannot always be completely removed. Flood risk management thus necessitates a comprehensive strategy that considers both the scientific and engineering aspects of rainfall, runoff, rivers, and flood inundation, as well as the human and socio-economic aspects of planning, development, and management. (MUTSO, 2011).

2.11 DATA ACQUISITION

The process by which useful information or data can be acquired will be used in finding solutions and control of flooding. Remote sensing is the best to be used in the cause of this project because it saves time and cost.

Data may be acquired in four different ways: gathering fresh data, converting or modifying historical data, sharing or trading data, and buying data. This covers automatic collecting (such as data collected from sensors), manually documenting empirical observations, and acquiring current data from external sources.

While obtaining data, several factors need to be taken into account (see below). For the data to be certified as suitable for their intended use by USGS, they must first be examined after being gathered or received to ensure that they meet requirements, (Chatfield, 2011).

2.11.1 Common Data Acquisition Considerations

Business needs: The first factor to always take into account is the necessity of the data for the business. What are you going to do with them?

Rules of Business: A business rule specifies the limitations that the company is subject to. For instance, all geographic data, if appropriate, must include metadata that complies with the Federal Geographic Data Committee (FGDC). Your choices of data collection will be impacted by these rules.

Data Standards: Any applicable USGS, government, or industry standards must be taken into account.

Accuracy Requirements: One of the most well-known accuracy needs is the locational precision for spatial data, but there are other accuracy requirements that you might need to take into account as well.

Cost: Cost is a factor in everything. When compared to collecting, buying can occasionally be more affordable.

Data correctness: It is important for many different kinds of work. For others, information might have to span a specific time frame. Others require data collected within a particular season. Photographs taken throughout the summer, when vegetation is at its densest, may be useful if you're attempting to estimate the amount of vegetation cover. Winter photographs could be useful if you're looking to find landforms.

Limited time: To what extent do you require the data right away?

Format: Do you require the information as flat files, Excel files, XML files, geographical data, photographs, or another format? Although it might not be applicable, you should nonetheless decide for each project, (Selbach, 2011).

Factors for Recently Collected Data

Volunteer/Contractor versus USGS The following considerations must be weighed when deciding who will carry out new data collection.

Skills: This collection's skill requirements may necessitate that it be contracted. Contracting could be the sole choice, for instance, if the necessary data can only be gathered by a qualified individual and the USGS is unable to find someone with that certification.

Frequency: Investing in internal collecting skills may not be necessary if data will only be collected once.

Timeliness: When will the data be needed? Is it time-critical?

In the USGS, most data are collected by employees and/or their contractors. While USGS can obtain some data from outside sources, we recognize that the bulk of an employee's work is the creation and maintenance of data, (Chatfield, 2011).

Data collecting is crucial to the data stewards because it is vital to the Bureau. There is a demand for cost-saving techniques in the data-gathering field. For instance, field data are increasingly being taken and entered straight from the source using GPS and mobile devices. The issue still exists that high-quality data must be first gathered at the source (where data may be directly connected with observation), where the tightest restrictions should be set up. Sadly, rigorous control has not yet been implemented at the source.

As a result, stringent controls must be in place when data are first gathered. Before gathering any information in the field, all of the analyses, definitions, and standards must be in place. Although it might seem obvious, this is not always done. A well-thought-out plan will lower this expensive line item.

To keep the quality of the data at a high level, it must be checked and updated often. Moreover, metadata needs to be updated simultaneously. While making choices, managers must feel confident that they are using the best data that is currently available. Metadata must be updated each time the data is modified. (February 2011).

2.11.2 Converted/Transformed Legacy Data Considerations

Legacy Quality: Is the data of a high enough standard to satisfy scientific requirements?

Technical Problems: Can you read the storage medium? Can the data be transformed into a useful format? at what price? (Chatfield, 2011).

2.11.3 Shared/Exchanged Data Considerations

Creating Data Sharing Agreements: Data Sharing Agreements must have clauses addressing distribution and access. As non-Federal companies are exempt from the Privacy Act, it is not advisable to sign into a data-sharing agreement where private information may be shared. The non-Federal entity must also be informed that the Federal agency may be required to provide material by the FOIA.

Data Structure: Is the information arranged in a useful way? Will it need to be modified or transformed before it can be put to use? Who will carry it out? What price?

Records Requirements: Data must include relevant metadata and other supporting documentation.

Completeness of the Data: The information is complete, right? If not, who will fill the data gaps? How much will it cost?

2.11.4 Considerations for Bought Data

Purchase Agreements: A Purchasing Agreement is necessary for data purchases. You are approving the data if you buy it. The Information Quality Act, which applies to all data, not only geographical data, is then applicable to such data.

Data certification: Metadata is necessary for data that has been purchased. The Buying Agreement should detail the particulars of this demand.

Problems with Licensing: Are there any limitations on how the data may be used? Do you need to take the Privacy Act or the FOIA into account? (Chatfield, 2011).

CHAPTER THREE

3.0 METHODOLOGY

3.1 STUDY AREA DESCRIPTION

Ikpoba-Okha is the study area, it is a local government area (L.G.A) of Edo State, Nigeria which has its headquarters in the town of Idogbo, Benin City, Edo State. It is located at latitude 6 18' 966" N and longitude 5o 37.992' E, with a population of 371,106 according to the 2006 census. The majority of the dwellers are members of the Bini ethnic division therefore, the Benin language is predominantly spoken in the area while Christianity and traditional religion are commonly practiced in the area. The important landmark in the area includes Benson Idahosa University (Manpower, 2013).

Ikpoba-Okha has a total area of 862 square kilometers and an average temperature of 28 degrees centigrade. The average humidity level of the area is at 69 per cent while the average wind speeds in the last glacial maximum (L.G.M) is 11km/h. The area is a humid, tropical urban settlement that is relatively flat due to its low topography. The research region has a cold climate and receives a lot of rain, especially during the rainy or wet season. Rainfall occurs throughout the year, with a yearly total of 2000-2300mm and a monthly average of around 180mm.

The development of lateralized reddish brown clayey sand covering extremely porous friable white sands, pebbly sands, and clay stringers with basal indurated ferruginous pebbly - coarse-grained sandstone is characterized by drifts and soil-cover soil cover in this location, (Manpower, 2013).

All geospatial data during this project will be imported into the GIS environment, after which geo-referencing will be done using the four coordinates points that will be obtained from the net of four known points while using the Universal Transverse Mercator System (UTM), the

geo-reference satellite image will be converted from raster to vector format in the GIS environment through digitization techniques as shown in figure 3.1.

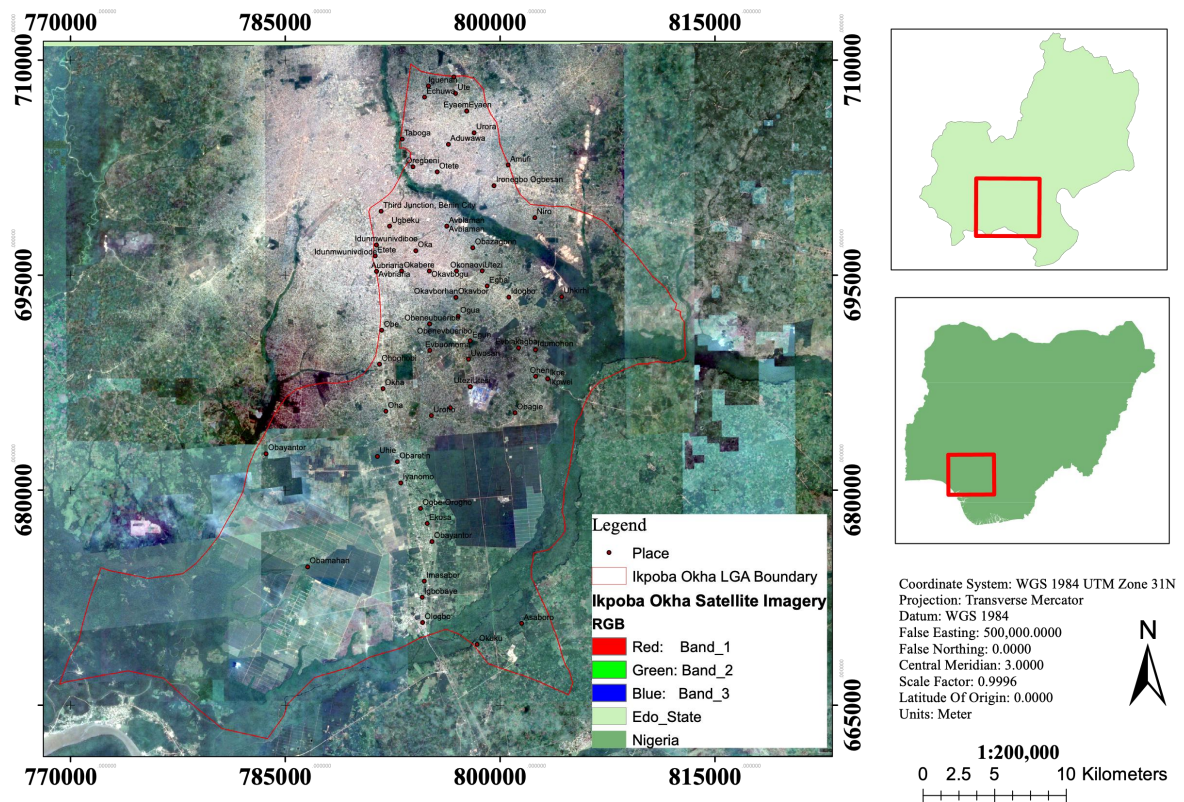


Figure 3.1: Study Area

3.2 DATA ACQUISITION

All imagery was downloaded from the USGS website and sent to a GIS application for processing.

3.3 HARDWARE AND SOFTWARE TO BE UTILIZED FOR THIS PROJECT

The following are included in the software applied in this work:

- a. **ArcGISv10.4:** this was the main software that does the task; it was used for the sub setting i.e. extraction of the region of interest from the imagery using both the administrative and local government boundary maps. It was also used for the display and subsequent processing and enhancement of the images.
- b. **Google Earth:** Used for reference in checkmating the maps of the study area

c. **Microsoft Word 2007**: This was used basically for the presentation of the research.

3.4 RAINFALL ANALYSIS OF THE STUDY AREA CALCULATION

For flood analysis (estimated mean rainfall) of the study area to be carried out, rainfall data from 2010 – 2019 was used for the calculation. The historical rainfall data (Giuseppe, 2019) contained annual rainfall parameters. Data from 2010 – 2020 was therefore used for the calculation of the data for 2010 and 2020 annual rainfall. This was done before calculating the mean annual rainfall.

The method used in getting the rainfall analysis was the Time series method using the Least Square in equation 3.1

$$x = \frac{Year-Origin}{halfofinterval} \quad (3.1)$$

Where; **Origin** = the mid-year, which for this project, was 2014.

Interval = 1 year apart/difference, therefore half is 0.5

Equations 3.2, 3.3, and 3.4 show steps in the final calculation of the least square approach

The final calculation for getting the annual mean rainfall value;

$$Y = a + by \quad (3.2)$$

a and b can be calculated using the formula below:

$$\sum y = na + b\sum x \quad (3.3)$$

$$\sum XY = a\sum x + b\sum x^2 \quad (3.4)$$

Where: **n** = number of years = 9, **a** and **b** are solved simultaneously

5. GENERATING THE DEM OF THE STUDY AREA

- a. The Digital Elevation Model (DEM) of the area was downloaded from USGS and imported into the ArcGIS environment.
- b. Using ArcGIS software, the border of the region of interest was defined. This was accomplished by:

- i. Generating a shape file for Edo state from a DEM acquired from the USGS and to acquire the Ikpoba-Okha Area shape file, open the Attribute table and pick Ikpoba-Okha to highlight it.
- ii. To conform with the border and show only the area of interest, the DEM was cropped using the clip tool from Geo-processing in ArcGIS software (Ikpoba-Okha).
- iii. Go to toolbox > spatial analysis tool > Re-class > Reclassify, where the lower elevations are labeled as the most floodable and the higher elevations as the least floodable.
- iv. The result will then be converted from raster to polygons using the ArcGIS software's conversion tool.
- v. Select ArcToolbox > Conversion Tools > From Raster > Raster to Polygon from the ArcToolbox menu.
- vi. Towns within the boundary area were added as inputs to identify the most and least affected areas (towns).
- vii. Source layer > click > selection > select by location Flood-proneness
Click "are completely within the source layer feature" from my spatial method for target layer feature > select by location.

3.6 GENERATING A LAND USE/LAND COVER

Figure 3.6 shows the flowchart of the methods that were followed in order to obtain a land use/land cover map of the study area (Ikpoba-Okha) using Sentinel-2 data downloaded from USGS.

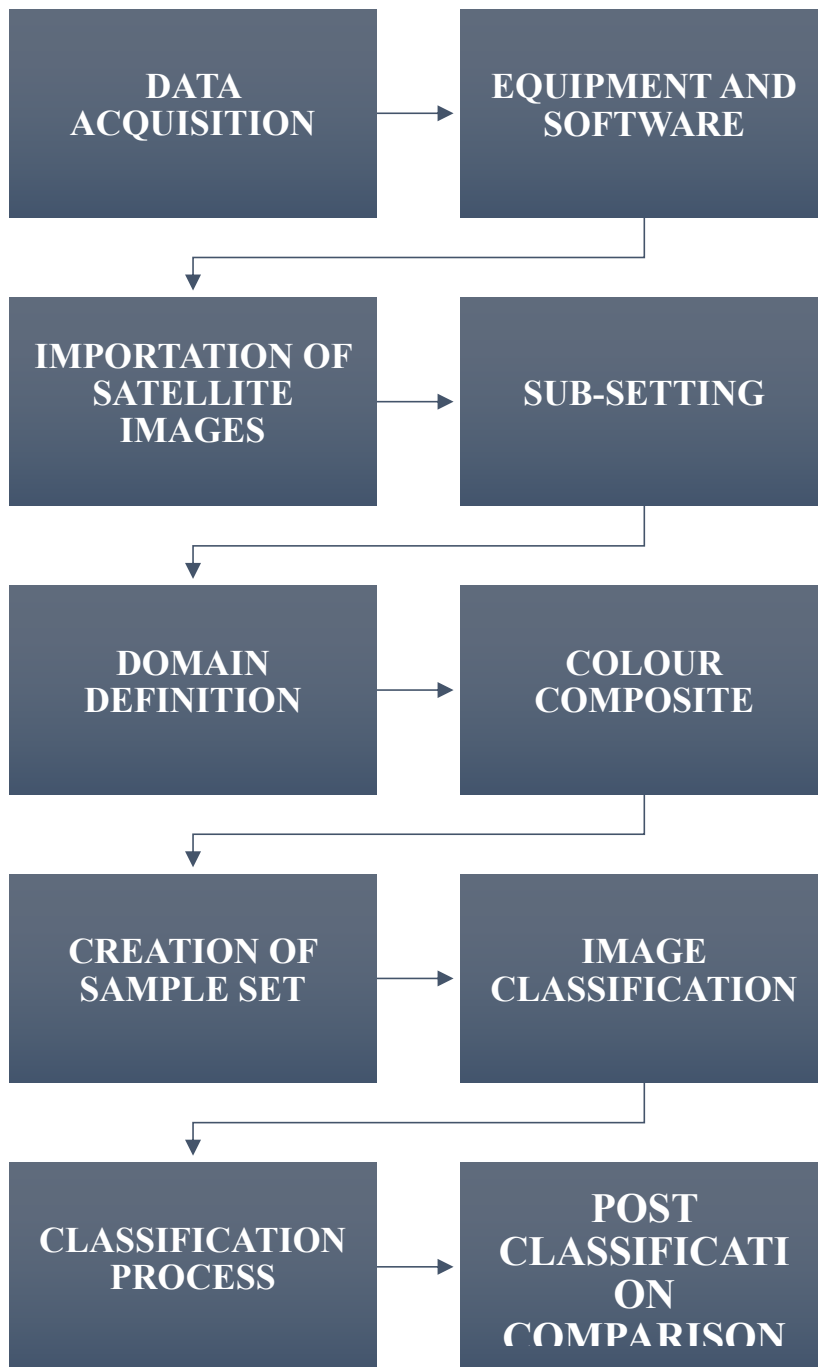


Figure 3.6: Flow chart showing land use/cover process

i. Data Gathering

The data are satellite imageries (Sentinel-2) of the research region downloaded from the United States Geological Survey for the year 2020 (USGS).

ii. Importing of Satellite images.

The first step was to extract the layers and stack the separate bands after getting the satellite pictures in zipping and geo-tiff files. The image was then loaded into ArcGIS vs10.4 environments from the file folder on computer hard disk C.

The following are the steps used for combining the different bands into a single multispectral layer (color composite)

- a) Select Windows from the drop-down menu (a drag-down list appears).
- b) Choose your image analysis (a window is displayed).
- c) Select all of the bands that will be stacked.
- d) Select "composite" from the drop-down menu.

iii. Sub Setting (creating an area of interest)

The coordinates of the bottom left and top right of the study area approximately will be obtained using an identifier in the software; the region of interest (ROI) was extracted from the whole satellite scene. This was done by using the shape file contained in the boundary layer of the study area obtained for the study. This was used to sub-map the area of interest from all the bands on the images imported. This was used to ensure the data quantity reduction and to focus on the area of interest. The process (in ArcGIS; subsetting) was repeated until all the bands were sub-settled.

The steps in the image sub-setting are;

- a) Go to the Arc toolbox (a drag-down list appears)
- b) Click on Spatial Analyst (a drag-down list appears)
- c) Select extraction (a drag-down list appears)
- d) Select extraction by mask (a new window is displayed)
- e) Provide the information requested and click OK.

iv. Domain Definition

The land use/land cover classes identified in the study area to be used in the image classification include bare surface, built-up area, rocks and vegetation.

v. Colour Composite

Colour composites for 2020 images will be formed by combining the three formed sub-bands raster into a single map so that a better visual impression of the reality on the ground is obtained than by displaying one band at a time. This will help in visualizing land cover types without any enhancement work.

The following steps are followed

- i. Go to Windows on the toolbar.
- ii. Click on image analysis (already the single bands were brought to the ArcGIS environment then add them to have a single multispectral band).
- iii. Go to the composite band to combine the selected layers to form a temporary multispectral layer.

vi. Creation of Sample Set

The sample set of 2020 from the map list image of each period was created. The domain classes such as; bare surface, built-up areas, rocks and vegetation were also created. The steps below show how to create training samples using the controls on the toolbar:

- i. On the toolbar, choose an appropriate image layer in the layer list.
- ii. Click the draw button. Notice that there are three drawing tools available, polygons, circles and rectangles.
- iii. In the map display, identify an area that belongs to a known class. Use the drawing tools to define training samples.
- iv. Once you finish drawing the training samples, a new class is created in the training sample manager with a default name, value, and colour. In the manager, change the

class name, value and colour if desired for the land, and repeat steps b-d to create a few more training samples to represent the rest of the classes on the image.

vii. Image Classification

This involves the location and delineation of selected cultural features and evidence of human activity or natural features. The identification of the imageries determines the class type of the study area. In this case, the classes that were identified are; built-up areas, bare surfaces, vegetation, and rocks. Image classification and analysis operations were used to digitally identify and classify pixels in the data.

viii. Classification Processes

This was done using ArcGIS software. You must first create “training areas” before the execution of the classification process. The classification process will be achieved through the following Steps;

- i. The first step is to activate the spatial analysis extension in ArcGIS (customize>extensions>spatial analyst).
- ii. Generate clusters: this unsupervised classification example uses the iso-clusters unsupervised classification method (spatial analysis tools>multivariate>iso-clusters).
- iii. The next step was naming and selecting colours for each class that were generated by the iso-clusters output.

iv. Post Classification Comparison

In post-classification, the image of 2020 was used to see the changes that occurred within these periods. The classified image was then run for post-classification comparison to produce a change detection analysis. Using the change detection statistical tool of the post-classification, the matrix table of the “from –to” change class will be obtained.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Digital Elevation Map

The map in figure 4.1 displays the Digital Elevation Model (DEM) of Ikpoba Okha Local Government Area (LGA) in Edo State. It uses a colour gradient legend to represent elevation values, ranging from dark green (-3 to 28m) to red (80 to 126m). The map has a scale of 1:200,000 and is projected in the WGS84/UTM Zone 31N coordinate reference system. A scale bar in kilometres is included for distance estimation. The map provides valuable insights into the topography of Ikpoba Okha LGA. The map revealed that the landform in the study area is relatively high as 80% of it is coloured tending towards red. During period of rainfall, the runoff from these areas acculates in locations where the topography is either low or relatively flat. The communities in these flat locations are then inuadated with severe flood leading to displacement and social disconnection of family members and loss of livelihood. The main drainage basin in the study area is Ikpoba river, it receives runoff from the entire catchment and empties it into river Eithope. During wet season (April to October), this river usually experiences overland flow which is responsible for severe hardship and economic losses.

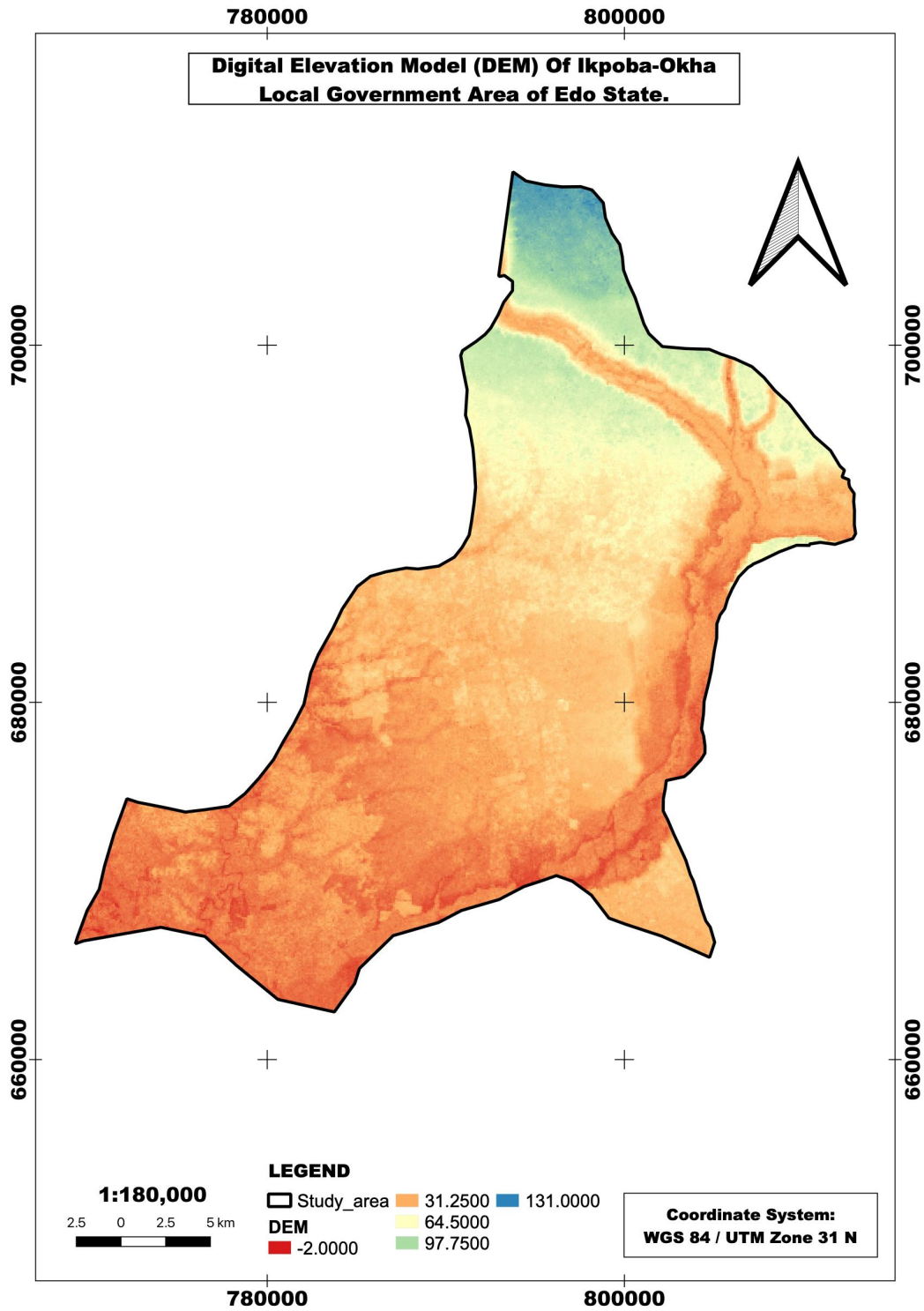


Figure 4.1: Map showing the Digital Elevation Model of Ikpoba Okha Local Government Area of Edo State

4.2 Flood Risk Map

The map in figure 4.2 depicts the flood risk and impact of flooding on towns within the Ikpoba Okha Local Government Area of Edo State. The legend categorizes flood risk levels with distinct colours, ranging from very low to very high. The study area is outlined in black, and towns are classified based on their level of flood impact. The map uses a scale of 1:200,000 and includes a scale bar in kilometres for accurate distance estimation. It serves as a valuable tool for understanding flood risk and prioritizing mitigation efforts in the area. The map shows how the likelihood of flood impact in the study area ranging from low to severe depending on the location. As revealed in figure 4.1, locations with high elevation are less susceptible to flooding and may likely not experience flooding all throughout the wet season. The same is not true for low lying locations within the catchment as it is highly susceptible to flooding. These communities are usually advised to seek alternative accommodation on the highland during wet season to prevent loss of lives and properties.

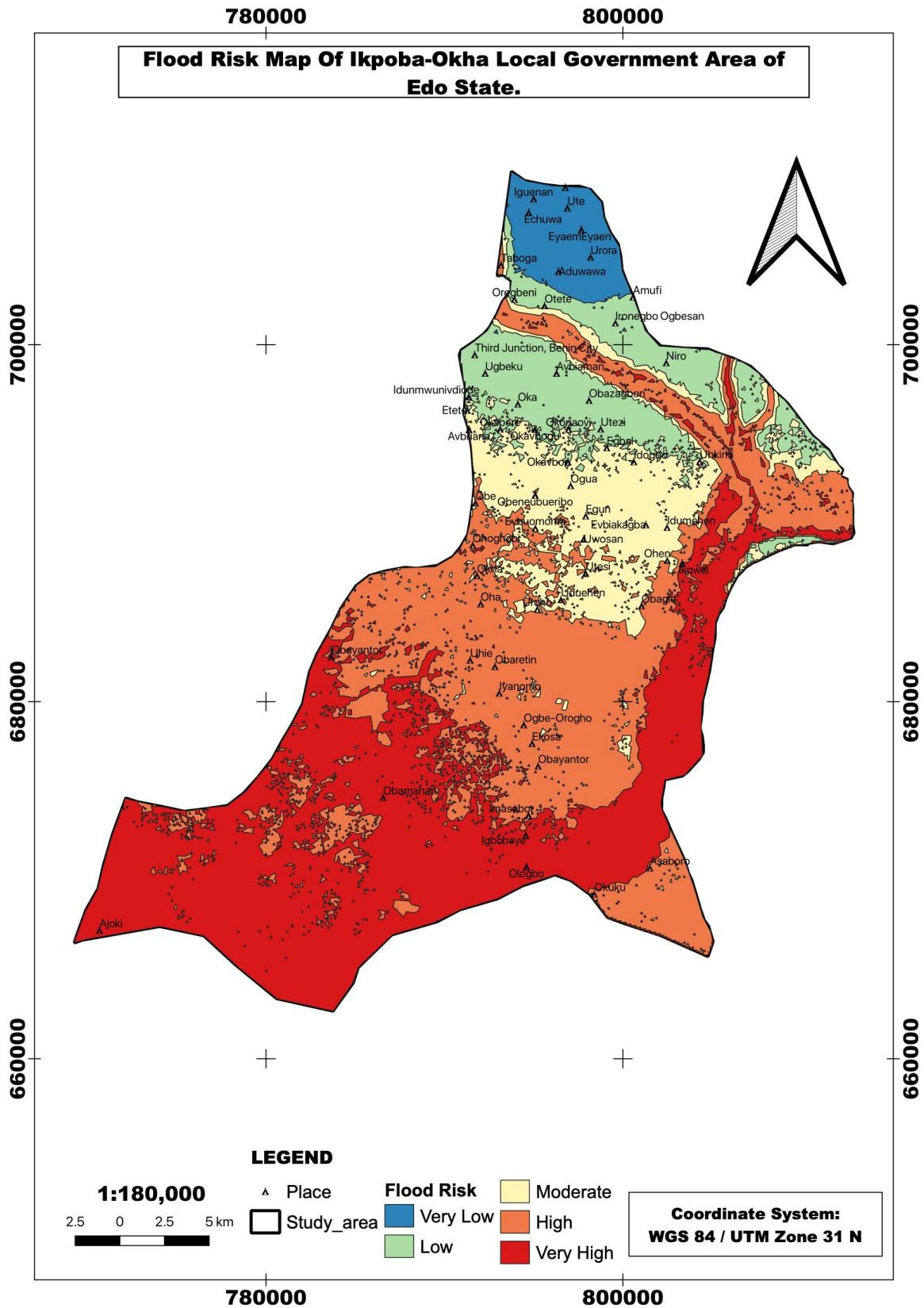


Figure 4.2: Map showing Flood risk of Ikpoba Okha Local Government Area of Edo State

4.3 Land Use/Cover Map

The land use and land cover of the Ikpoba okha Local Government Area (LGA) in Edo State, Nigeria, is shown on figure 4.3 expert map. It employs the WGS84/UTM Zone 31N coordinate reference system at an estimated scale of 1:200,000. The legend makes it apparent which aspects are depicted: the black limits of the Ikpoba okha LGA and Red for settlement, the dark green vegetation, Lite green Agricultural area, and the blue water body. The map's function is highlighted in the title, and measuring distance is made easier with a scale bar in kilometres. Overall, it is a useful visual aid for comprehending local land use trends.

The catchment area as revealed by figure 4.3 is fairly built up (about 42%) while the agririan land is about 51%. The other available spaces are for other land use type which makes the area a bit exposed to the devastating effects of flooding. The barelands are not completely exposed as there appears to be some vegetative cover. This helps to prevent soil loss and displacement of soil particles from one place to another.

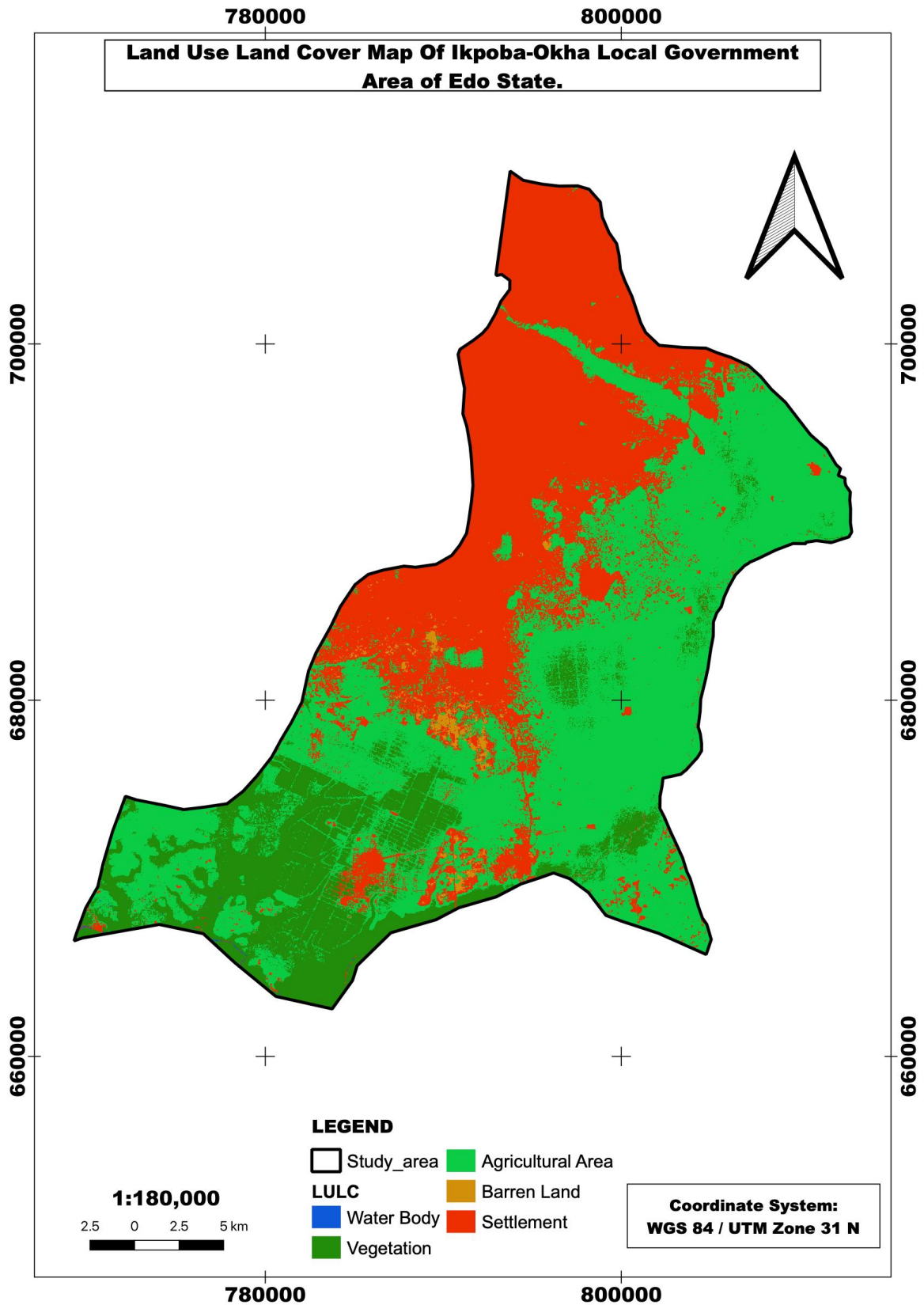


Figure 4.3: Map showing Land Use Land Cover Map of Ikpoba Okha Local Government Area of Edo State

4.4 Vulnerability Map

The Vulnerability map employs the WGS84/UTM Zone 31N coordinate reference system at an estimated scale of 1:200,000. The legend makes it apparent which aspects are depicted: dark green for very low vulnerability, light green for low vulnerability, yellow for moderate vulnerability, orange for high vulnerability and Red for very high vulnerability. The map's function is highlighted in the title, and measuring distance is made easier with a scale bar in kilometers. Overall, it is a useful visual aid for comprehending local land use trends.

The vulnerability map revealed the entire area in the catchment that is a high risk of flooding during the wet season. Areas in the north eastern location are highly vulnerable to flood challenges while other parts of the catchment are not.

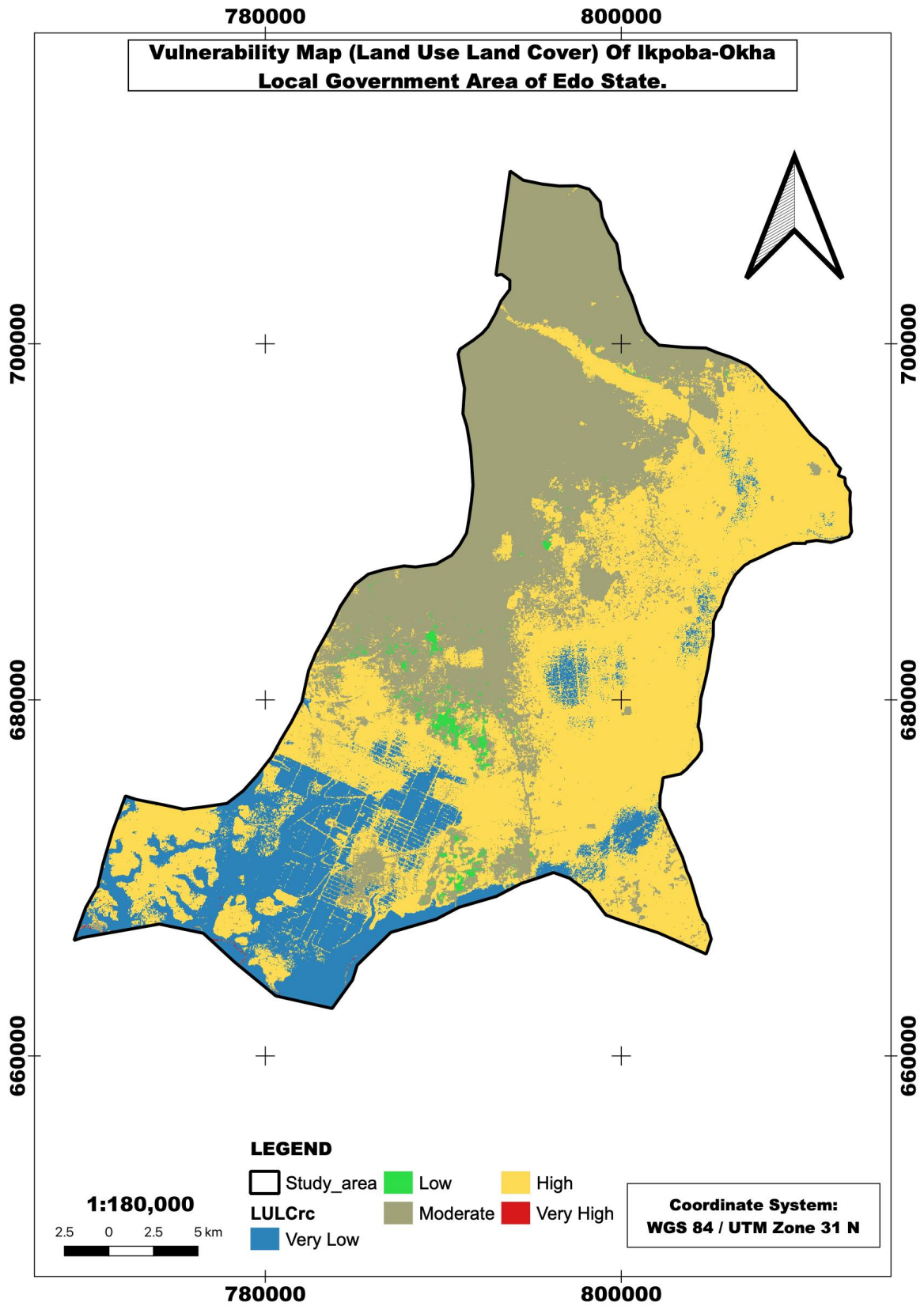


Figure 4.4: Map showing Vulnerability (Land Use Land Cover) map of Ikpoba Okha Local Government Area of Edo State

4.1 Calculation of Rainfall Analysis of the Study Area

The rainfall analysis of the study area was determined using table 4.1. The table 4.1 contains historical rainfall data from 2012 – 2020. This was used to further estimate volume of rainfall in the study area for year 2021 and 2022 using equation 4.1.

Table 4.1: Annual rainfall Values (2010 -2018)

Year	Y (annual rainfall) mm
2012	2087.3
2013	2369.8
2014	2251.2
2015	1701.6
2016	1589.3
2017	2567.4
2018	1894.2
2019	2734.8
2020	2674.0

Using the Time series Least Square method we have;

$$x = \frac{Year-Origin}{half\ of\ interval} \quad (4.1)$$

Where; Origin = the mid-year, which is 2016 in this case

Interval = 1 year apart, therefore half is 0.5

$$x = \frac{2012 - 2016}{0.5} = -8$$

$$x = \frac{2013 - 2016}{0.5} = -6$$

$$x = \frac{2014 - 2016}{0.5} = -4$$

$$x = \frac{2015 - 2016}{0.5} = -2$$

$$x = \frac{2016 - 2016}{0.5} = 0$$

$$x = \frac{2017 - 2016}{0.5} = 2$$

$$x = \frac{2018 - 2016}{0.5} = 4$$

$$x = \frac{2019 - 2016}{0.5} = 6$$

$$x = \frac{2020 - 2016}{0.5} = 8$$

Table 4.2: Complete table of annual rainfall

Year	Y(annual rainfall) mm	X	XY	X ²
2012	2369.8	-8	-18958.4	64
2013	2251.2	-6	-13507.2	36
2014	1734.8	-4	-6939.2	16
2015	1674.0	-2	-3348	4
2016	1701.6	0	0	0
2017	1589.3	2	3178.6	4
2018	2567.4	4	10269.6	16
2019	1940.3	6	11641.8	36
2020	1933.1	8	15464.8	64
	$\Sigma = 17761.5$	$\Sigma = 0$	$\Sigma = 7187.2$	$\Sigma = 240$

To get the annual rainfall mean value we first find data for 2021 and 2022, therefore, equation 4.2 was used:

$$Y = a + bx \tag{4.2}$$

a and b can be calculated using equation 4.3 and 4.4 respectively;

$$\sum y = na + b\sum x \tag{4.3}$$

$$\sum XY = a\sum x + b\sum x^2 \tag{4.4}$$

Where: **n** = number of years = 9

Using the input for each data, **a** and **b** are 1973.5 and 29.947 respectively.

The **x** values for 2021 and 2022 are **10** and **12** respectively.

Using the formula in equation 4.2, we have the annual rainfall value for 2021 and 2022 as **2273.0mm** and **2332.9mm** respectively.

Finally, the mean annual rainfall for duration of 11 years (2012 – 2022) was calculated to be **2033.4mm**.

According to this method of analysis, the annual rainfall for 2021 and 2022 under a regression pattern, this method can also be used for predicting future rainfall analysis.

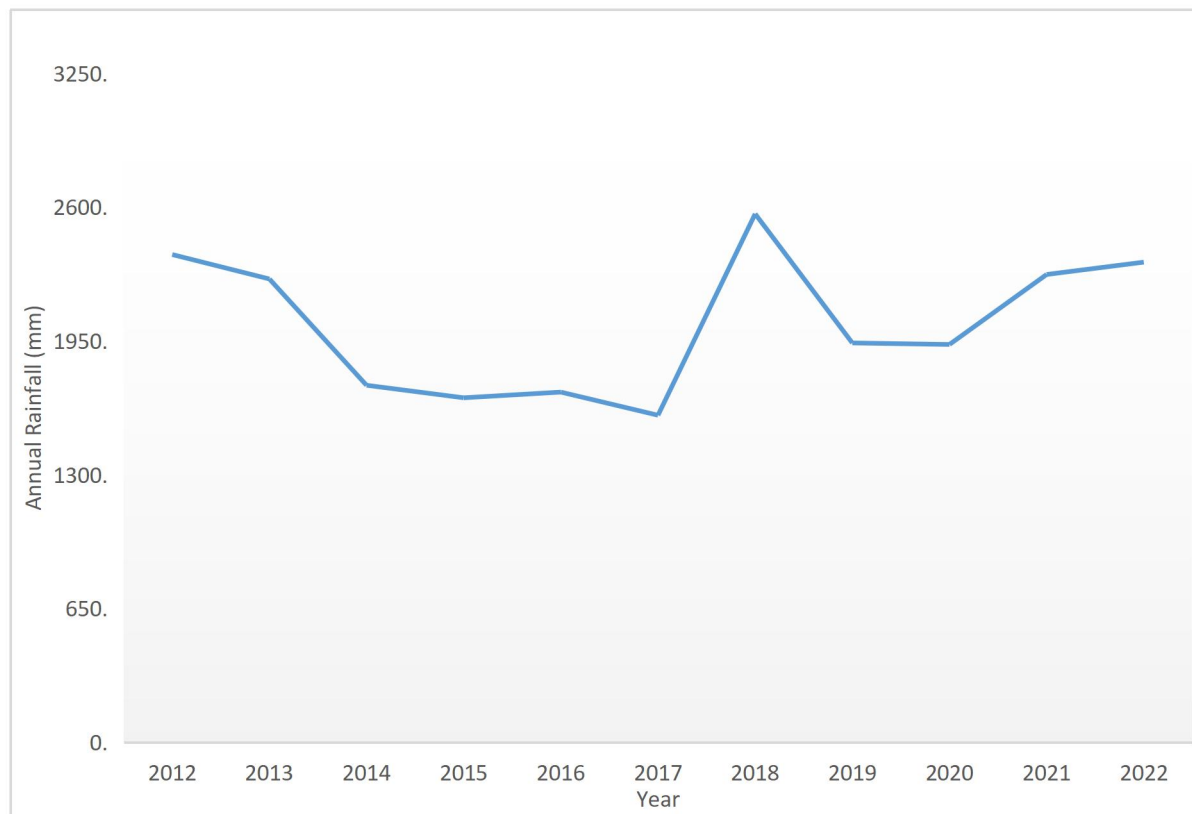


Figure 4.1: Graph showing annual rainfall from 2010 - 2020

4.2 ANALYSIS OF FLOOD MAPS GENERATED

4.2.1 Land Use/Cover Map

The research region's land use/cover map was created using the ArcGIS program. This map gave crucial information to better understand the study area's contemporary landscape, including; i. Area Built-Up. ii. Flooded vegetation. iii. Ground bare. There are trees and other details on the map.

The LULC map was created based on historical data obtained in the study area, the results which revealed high rainfall, which occurs consistently across the research region, was the main cause of flooding. The absence of effective drainage systems in built-up regions may be to blame for the fact that the places most impacted by flooding were not built areas (areas with buildings on top of natural settlements). This is consistent with the historical account, which ascertained that poor drainage is the second-leading cause of floods in the study area.

4.2.2 Flood Risk Map

The DEM and information acquired from the downloaded satellite images were utilized to build the flood risk map, which was likewise produced using ArcGIS software. This map displayed the research area's flood-prone and risky locations.

The produced map displays class data that is also consistent with the Land Use/Cover map, such as;

- i.** Towns impacted
- ii.** Towns are not impacted
- iii.** Areas Most Prone to Flood
- iv.** Less prone to flooding (towns)
- v.** Moreover, the research area's perimeter

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Since its inception, development, and integration, remote sensing and geographic information systems have both been essential in combating floods on a worldwide scale. However, there is still work to be done in terms of controlling this crisis. No area of human growth, observation, management of natural resources, engineering, or technology is exempt from the critical role that remote sensing and GIS play. When it comes to obtaining, storing, manipulating, and displaying geographical and non-spatial information in an integrated fashion, GIS often offers the most effective, efficient, and, of course, economical tool.

The most recent and accurate maps/GIS database is a requirement for this because activities like planning, design, marking out key areas, etc., require an accurate and detailed large-scale GIS database of the entire area.

The following are some of the causes of flooding in the Ikpoba-Okha Area, according to historical data (Giuseppe, 2019).

1. One of the key variables is heavy rain, which accounts for 40%

2. Poor construction or inadequate drainage, which accounts for 31% (can also include blockage of waterways)
3. 11% of the natural settlement may be built on.
4. Unwise land use and planning, which account for 18%

As we saw in the earlier section, constructing or generating a flood map is of utmost importance when it comes to flood assessment. Remote sensing combined with GIS can immediately provide a map of the research area/region covered.

In conclusion, identifying, analyzing, and managing the numerous natural and man-made catastrophes requires an integrated strategy that incorporates input/data from a variety of diverse/different methodologies. To support the efficient operation of the entire system and effective collaboration, coordination at all levels must be assured. It is also crucial that disaster management and environmental organizations have access to large-scale digital map data with detailed information about each disaster to suggest effective and potential remedies.

5.2 RECOMMENDATIONS

The author suggests doing the following:

- i. Conducting further research on the study region, particularly concerning changes in that area's climate, land usage, etc.
- ii. Suggest an effective strategy or course of action for decreasing flood catastrophes in the study. Examples include installing a dependable drainage system and eliminating artificial obstructions to natural settlements.
- iii. Evaluate the efficiency of the procedures presently in place for flood mitigation measures, such as a review of the current flood control proposal, and if feasible, suggest better/appropriate steps.
- iv. Reforestation, or the planting of green plants, in impacted regions
- v. Create an early warning system for the impacted cities and communities.

- vi. Train staff to be professionals and specialists in addressing flood catastrophe issues and other environmental calamities.

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